

INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART THREE MACHINERY INSTALLATIONS

Table of Contents

RULES FOR CLASSIFICATION OF 1

PART THREE MACHINERY INSTALLATIONS 1

CHAPTER 1 GENERAL 1
Section 1 REQUIREMENTS FOR CLASSIFICATION 1
Section 2 GENERAL PROVISIONS 1
Section 3 ARRANGEMENT 4
CHAPTER 2 PUMPING AND PIPING SYSTEMS 6
Section 1 GENERAL PROVISIONS 6
Section 2 CARBON, LOW ALLOY STEELS AND stainless steels 8
Section 3 COPPER AND COPPER ALLOYS 11
Section 4 OTHER MATERIALS 14
Section 5 CONNECTION OF PIPE LENGTHS, HEAT TREATMENT AND NON-DESTRUCTIVE TESTING 15
Section 6 PUMPS, VALVES AND FITTINGS 20
Section 7 TESTS 21
Section 8 ARRANGEMENT 23
Appendix 1 PRODUCTION AND APPLICATION OF PLASTIC PIPING SYSTEMS ON SHIPS 27
Appendix 2 FLEXIBLE HOSES 35
Appendix 3 TYPE APPROVAL OF MECHANICAL JOINTS 37
Appendix 4 AIR PIPE CLOSING DEVICES 43
CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS 47
Section 1 GENERAL PROVISIONS 47
Section 2 DRAINAGE OF COMPARTMENTS, OTHER THAN MACHINERY SPACES 47
Section 3 BILGE DRAINAGE OF MACHINERY SPACES 49
Section 4 BILGE PUMPS AND BILGE PIPING 50
Section 5 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE FOR PASSENGER SHIPS 54
Section 6 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE 54
Section 7 DRAINAGE ARRANGEMENTS AND BALLAST PIPING FOR NON-SELF-PROPELLED SHIPS 55
Section 8 BALLAST AND SCUPPER SYSTEMS 56
Section 9 REMOTELY CONTROLLED BILGE AND 57
BALLAST SYSTEMS 57
Section 10 AIR, OVERFLOW AND SOUNDING PIPES 57
Section 11 VENTILATION 60
Section 12 ADDITIONAL REQUIREMENTS TO WATER LEVEL DETECTION AND DEWATERING OF FORWARD SPACES OF BULK CARRIERS 61
CHAPTER 4 MACHINERY PIPING SYSTEMS 63
Section 1 GENERAL PROVISIONS 63
Section 2 OIL FUEL SYSTEMS 63
Section 3 STEAM PIPING SYSTEMS 68
Section 4 FEED, BLOW-OFF AND CONDENSATE SYSTEMS 69
Section 5 COOLING WATER SYSTEMS 70
Section 6 LUBRICATING OIL SYSTEMS 70
Section 7 HYDRAULIC TRANSMISSION PIPING SYSTEMS 72
Section 8 THERMAL OIL SYSTEM 72
Section 9 REQUIREMENTS CONCERNING USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS 74
Section 10 EXHAUST PIPELINES 76
CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS 77
Section 1 GENERAL PROVISIONS 77
Section 2 CARGO HANDLING SYSTEM 78
Section 3 BILGE, BALLAST AND OTHER PIPING SYSTEMS 80
Section 4 CARGO OIL HEATING 81
Section 5 CARGO TANK LEVEL SOUNDING 82
Section 6 CARGO TANK VENTING ARRANGEMENTS 82

Section 7 REQUIREMENTS FOR DOUBLE HULL SPACES OF 84
OIL TANKERS 84
Section 8 REQUIREMENTS FOR OIL TANKERS INTENDED FOR CARRIAGE OF CARGO OIL HAVING A FLASH POINT EXCEEDING 84
60℃ 84
CHAPTER 6 BOILERS AND PRESSURE VESSELS 85
Section 1 GENERAL PROVISIONS 85
Section 2 DESIGN AND MANUFACTURE 86
Section 3 BOILER MOUNTINGS AND FITTINGS 90
Section 4 FITTINGS OF PRESSURE VESSELS 94
Section 5 THERMAL OIL HEATERS 95
Section 6 INSTALLATION AND TEST 96
Appendix 1 STRENGTH CALCULATION OF 98
WATER TUBE BOILERS 98
Appendix 2 STRENGTH CALCULATION OF HORIZONTAL 108
SMOKE TUBE BOILERS 108
Appendix 3 STRENGTH CALCULATION OF VERTICAL 116
AUXILIARY BOILERS 116
Appendix 4 STRENGTH CALCULATION OF 120
PRESSURE VESSELS 120
Appendix 5 OPENINGS AND COMPENSATION 121
Appendix 6 STRENGTH CALCULATION OF STANDPIPES, DOORS FOR MANHOLES AND SIGHT HOLES 125
CHAPTER 7 STEAM TURBINES 126
Section 1 GENERAL PROVISIONS 126
Section 2 MATERIALS 126
Section 3 DESIGN 127
Section 4 FITTINGS 127
Section 5 TESTS AND TRIALS 129
CHAPTER 8 GAS TURBINES 132
Section 1 GENERAL PROVISIONS 132
Section 2 MATERIALS 133
Section 3 DESIGN AND CONSTRUCTION 133
Section 4 FITTINGS 135
Section 5 TESTS AND TRIALS 136
CHAPTER 9 DIESEL ENGINES 138
Section 1 GENERAL PROVISIONS 138
Section 2 INSPECTION, TEST AND CERTIFICATION OF DIESEL ENGINE PARTS 142
Section 3 DESIGN AND CONSTRUCTION 144
Section 4 PIPING SYSTEMS 145
Section 5 STARTING ARRANGEMENTS 146
Section 6 SCAVENGING AND SUPERCHARGING ARRANGEMENTS 147
Section 7 FITTINGS 150
Section 8 INSTALLATION 154
Section 9 ALARMS AND SAFEGUARDS FOR EMERGENCY DIESEL ENGINES 155
Section 10 SURVEY AND CERTIFICATION 155
Appendix 1 SAFETY OF LOW PRESSURE GAS FUEL ENGINES 158
Appendix 2 GUIDELINES FOR ELECTRONICALLY CONTROLLED 166
DIESEL ENGINES 166
Appendix 3 APPRAISAL OF CRANKSHAFT STRENGTH OF 170
DIESEL ENGINES 170
Appendix 4 TYPE TEST OF DIESEL ENGINES 226
Appendix 5 APPROVAL AND CERTIFICATION OF DIESEL ENGINES 230
Appendix 6 WORKS ACCEPTANCE TEST AND SHIPBOARD TRIALS OF DIESEL ENGINES 243
Appendix 7 TYPE TESTING PROCEDURE FOR CRANKCASE EXPLOSION RELIEF VALVES 247
Appendix 8 TYPE TESTING PROCEDURE FOR CRANKCASE OIL MIST DETECTION AND ALARM EQUIPMENT 251
Appendix 9 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL 255

Appendix 10 SAFETY OF METHANOL/ETHANOL FUEL ENGINES 259
CHAPTER 10 TRANSMISSION GEARING 266
Section 1 GENERAL PROVISIONS 266
Section 2 MATERIALS 266
Section 3 DESIGN AND CONSTRUCTION 267
Section 4 TESTS 269
Appendix 1 APPRAISAL OF GEAR STRENGTH 270
CHAPTER 11 SHAFTING AND PROPELLERS 302
Section 1 GENERAL PROVISIONS 302
Section 2 SHAFTING 303
Section 3 SHAFT TRANSMISSION UNITS 306
Section 4 PROPELLERS 310
CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT 317
Section 1 GENERAL PROVISIONS 317
Section 2 TORSIONAL VIBRATION 319
Section 3 AXIAL VIBRATION 323
Section 4 WHIRLING VIBRATION 324
Section 5 SHAFTING ALIGNMENT 324
Appendix 1 ENHANCED SHAFT ALIGNMENT 328
CHAPTER 13 STEERING GEAR AND WINDLASSES 330
Section 1 STEERING GEAR 330
Section 2 ①WINDLASSES 337
Appendix 1 GUIDELINES FOR THE ACCEPTANCE OF NON-DUPLICATED RUDDER ACTUATORS FOR TANKERS, CHEMICAL TANKERS AND GAS CARRIERS OF 10,000 GROSS TONNAGE AND UPWARDS BUT OF LESS THAN 100,000 TONS DEADWEIGHT 342
CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE 344
Section 1 GENERAL PROVISIONS 344
Section 2 PROPULSION MACHINERY 346
Section 3 STARTING ARRANGEMENTS AND COOLING WATER SYSTEM 367
CHAPTER 15 VAPOUR CONTROL SYSTEM 368
Section 1 GENERAL PROVISIONS 368
Section 2 VAPOUR PIPING SYSTEMS 369
Section 3 INSTRUMENTATION 370
Section 4 ADDITIONAL REQUIREMENTS FOR VCS-T 371
Section 5 INSTRUCTION MANUAL 371
CHAPTER 16 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS OF SMALL SHIPS 373
Section 1 GENERAL PROVISIONS 373
Section 2 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS 373

CHAPTER 1 GENERAL

Section 1 REQUIREMENTS FOR CLASSIFICATION

1.1.1 Conditions of classification for machinery installations

1.1.1.1 Main propulsion and auxiliary machinery installations together with their associated equipment, boilers, pressure vessels, pumping and piping systems, and gearing fitted in ships are to comply with the relevant requirements prescribed in this PART.

1.1.1.2 For the requirements for machinery installations of small ships and ships in restricted service, reference is made to the provisions in Chapter 16 of this PART and Chapter 3 of PART TEN.

1.1.1.3 In addition, the machinery installations are to comply with the applicable requirements of PART ONE of the Rules.

1.1.2 Class notations

1.1.2.1 For the specific class notations of ships, reference is made to the relevant provisions in Chapter 2, PART ONE of the Rules.

1.1.3 Plans and documents

1.1.3.1 Prior to the commencement of ship construction, plans and documents as listed in the respective Chapters of this PART are to be submitted for approval. Other plans and documents may be required to be submitted as deemed necessary for individual cases.

1.1.3.2 Any major alterations to basic design, materials or other aspects of the approved plans are to be re-submitted to ISC for approval.

1.1.3.3 For products approved by ISC, the submission of such plans and detailed information are not necessary.

1.1.4 Product survey

1.1.4.1 For the certification requirements and product survey of machinery installations, reference is made to the relevant provisions in Chapter 3, PART ONE of the Rules.

Section 2 GENERAL PROVISIONS

1.2.1 Ambient conditions

1.2.1.1 The main and auxiliary engines, shafting and machinery equipment essential to classification are to be so designed, type-selected and arranged as to ensure normal operation under the inclination conditions as shown in Table 1.2.1.1. Considering the type, size and service conditions of the ship, smaller angles of inclination may be permitted.

Angle of inclination of ships **Table 1.2.1.1**

Installations and equipment	Angle of inclination① (º)			
	Athwartships		Fore-and-aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22.5	5②	7.5
Safety equipment: e.g. emergency power installations, emergency fire pumps and their device	22.5③	22.5③	10	10

Notes: ① Athwartships and fore-and-aft inclinations may occur simultaneously.

② Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as $500/L$ degrees, where L = length of the ship, in m.

③ For ships carrying liquefied gases and chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

1.2.1.2 The machinery installations relevant to classification of ships are to be so designed and arranged as to ensure normal operation under the ambient temperature conditions as shown in Table 1.2.1.2.

For ships in restricted service, ambient temperature may be taken according to the actual condition of

navigation area.

Ambient temperature **Table 1.2.1.2**

Environment	Location	Temperature range (℃)
Air	In enclosed spaces	0 to 45
	Within specific space or on machinery installations	According to actual temperature of specific space or equipment
	On the open deck	-25 to 45
Seawater	All positions	32

1.2.1.3 For the purpose of determining the rating of main and auxiliary reciprocating internal combustion engines, the following ambient reference conditions apply to ships for unrestricted service:

Total barometric pressure 0.1 MPa
Air temperature 45℃
Relative humidity 60%
Sea water temperature (charge air coolant-inlet) 32℃

The engine manufacturers are not expected to provide simulated ambient reference conditions at a test bed.

1.2.1.4 In the case of ships for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service.

1.2.2 Vibration

1.2.2.1 The propulsion installations are to be so designed, constructed and installed that any mode of their vibrations is not to cause undue stresses in them in the normal operating ranges.

1.2.3 Strengthening for navigation in ice

1.2.3.1 For ships navigating in ice and granted relevant additional notations, their main propulsion machinery and auxiliary equipment are to comply with the provisions of Chapter 14 of this PART.

1.2.4 Astern power

1.2.4.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolution.

1.2.4.2 Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolution for a period of at least 15 min. The astern trial is to be limited to 30 min or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

1.2.4.3 For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of propulsion machinery.

1.2.4.4 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics. The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these are to be included in the test plan[①].

1.2.4.5 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials[②].

1.2.5 Overload power

1.2.5.1 Prime movers of main engines and electric generators are to be capable of running at an overload power corresponding to 110% of its rated power.

1.2.6 Dead ship starting

1.2.6.1 Ship's machinery is to be so arranged that it can be brought into operation from the dead ship condition using only the facilities available on board without external aid.

---

① This paragraph applies to:
(1) ships contracted for construction on or after 1 July 2018.
(2) ships other than those specified in the preceding (1) on which astern testing is carried out in accordance with 5.9.4.10, Chapter 5, PART ONE of the Rules on or after 1 July 2018.

② Same as ① above.

Dead ship condition is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.
Where the emergency source of power is an emergency generator which complies with 9.5.3 of this PART and 2.2.1.6 of PART FOUR of the Rules, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.
Where there is no emergency generator installed or an emergency generator does not comply with the above-mentioned requirements, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor.
The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 min of a dead ship condition. For steam main propulsion unit, 30 min means time from dead ship condition to successful ignition of first main boiler.

1.2.7 Automation of machinery installations

1.2.7.1 Automatioin for machinery installations is to comply with the relevant requirements of PART SEVEN of the Rules.

1.2.8 Materials

1.2.8.1 The materials used in the construction of main components for main propulsion and auxiliary machinery installations and propulsion shafting systems, boilers and pressure vessels are to be in compliance with the relevant requirements of ISC Rules for Materials and Welding.

1.2.8.2 For all ships, new installation of materials which contain asbestos are prohibited.

1.2.9 Fuel

1.2.9.1 The flash point (closed cup test) of oil fuel for the main propulsion machinery and prime movers to drive generators or boilers are, in general, not to be less than 60℃ For the prime movers of emergency generators, oil fuel having a flash point of not less than 43℃ is permissible.

1.2.9.2 The use of oil fuel having a flashpoint of less than 60℃ but not less than 43℃ may be permitted (e.g. for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A) subject to the following:

(1) fuel oil tanks except those arranged in double bottom compartments are to be located outside of machinery spaces of category A;

(2) provision for the measurement of oil temperature are to be provided on the suction pipe of the oil fuel pump;

(3) stop valves and/or cocks are provided on the inlet side and outlet side of the oil fuel strainers;

(4) pipe joints of welded construction or of circular cone type or spherical type union joint are to be applied as much as possible;

(5) the whole fuel system is to be located outside the machinery spaces of category A;

(6) the arrangement of fuel oil tank is to comply with the requirements of 3.2.1.5(1)-(5) of Chapter 3 of PART SIX of the Rules.

1.2.9.3 In cargo ships the use of fuel having a lower flashpoint than 43℃ may be permitted provided that such fuel is not stored in any machinery space and the arrangement for the complete installation has been submitted for approval.

1.2.9.4 Ships using distillates with a sulphur content not more than 0.10% m/m are to comply with the relevant requirements of this PART and in addition, the requirements of ISC Guidelines for Use of Low Sulphur Distillate Fuels in Ships.

1.2.10 Emission treatment

1.2.10.1 Ships installed with exhaust gas cleaning systems (hereinafter referred to as the EGC systems) for reduction of SO_x emission from fuel oil combustion units are, in addition to the relevant provisions of this PART, to comply with the requirements of ISC Guidelines for Testing and Survey of Exhaust Gas Cleaning Systems and Guidelines for Design and Installation of Exhaust Gas Cleaning Systems.

1.2.10.2 Ships installed with selective catalytic reduction systems (hereinafter referred to as the SCR

systems) for reduction of NO_x emission from diesel engines are, in addition to the relevant provisions of this PART, to comply with the requirements of ISC Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) systems and Guidelines for Application of Selective Catalytic Reduction (SCR) Systems Onboard Ships.

1.2.10.3 Ships installed with exhaust gas recirculation systems (hereinafter referred to as the EGR systems) and related auxiliary systems for reduction of NOx emission from diesel engines are, in addition to the relevant provisions of this Part, to comply with the requirements of ISC Guidelines for Application of Exhaust Gas Recirculation Systems onboard Ships.

1.2.11 Clean energy and power

1.2.11.1 Ships other than liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Rules for Natural Gas Fuelled Ships.

1.2.11.2 Liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers.

1.2.11.3 Liquefied gas carriers using liquefied gas other than natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of 16.9, Chapter 16, PART THREE of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

1.2.11.4 Ships using methyl/ethyl as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Guidelines for Ships Using Methanol/Ethanol Fuel.

1.2.11.5 Ships using biodiesel fuel or the mixture of biodiesel and regular fuel as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of Pt. 3 of the Guidelines for Ships Using Alternative Fuel.

1.2.11.6 Ships provided with the fuel cell power system are, in addition to the relevant provisions of this PART, to comply with relevant requirements of Pt. 2 of the Guidelines for Ships Using Alternative Fuel.

1.2.12 Trials

1.2.12.1 The mooring and sea trials for machinery installations are to be carried out in accordance with the relevant provisions of the Rules and the approved test programs.

On completion of the trials, corresponding technical documents and trial reports are to be furnished by the shipyard.

Section 3 ARRANGEMENT

1.3.1 Means of escape

1.3.1.1 Means of escape in machinery spaces are to comply with the requirements specified in PART SIX of the Rules.

1.3.2 Boiler arrangement

1.3.2.1 Where boilers are located in machinery spaces on tween-decks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the tween-decks are to be provided with coamings at least 200 mm in height to prevent the oily water that might leak from spreading and dropping to the lower level. This area may be drained to the bilges. The drain tank is not to form part of an overflow system.

1.3.2.2 The clearance between boilers and fuel oil tank boundaries is not to be less than that specified in Table 1.3.2.2.

The clearance between boilers and fuel oil tank boundaries (mm) Table 1.3.2.2

		Top plate of double-bottom fuel oil tank	Fuel oil bulkhead
Water-tube boiler	Outer wall	—	450
	Bottom	600	—
Fire-tube boiler	End plate	—	600
	Bottom	450	—

1.3.3 Skylights of machinery casings

1.3.3.1 Skylights located in machinery spaces of category A are to be of steel and are not to contain glass panels. Suitable arrangements are to be made to permit the release of smoke in the event of fire, from the

space to be protected.

1.3.4 Ventilation

1.3.4.1 Machinery spaces are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

1.3.4.2 All spaces, where flammable or toxic gases or vapors may accumulate, are to be provided with adequate ventilation.

1.3.5 Position of emergency equipment on passenger ships

1.3.5.1 Emergency sources of electrical power, fire pumps, bilge pumps except those specifically serving the spaces forward of the collision bulkhead, any fixed fire-extinguishing system required in PART SIX of the Rules and other emergency installations which are essential for the safety of the ship, except anchor windlasses, are not to be installed forward of the collision bulkhead.

1.3.6 Protection

1.3.6.1 In places where the working of machinery and equipment may cause injuries to the operating personnel, handrails, protecting casings or screens are to be provided.

1.3.6.2 Placards or labels are to be provided for illustrating the correct procedures of operation, so as to avoid any mistakes in the operation or change-over of the machinery or systems.

1.3.6.3 All surfaces of machinery and pipes where the hot surfaces may injure personnel are to be protected by handrails or shields. Where the surface temperature may exceed 220℃, they are to be effectively shielded to prevent ignition caused by flammable liquids. Where the insulation covering these surfaces is oil-absorbing or previous to oil, such insulation is to be encased in steel or equivalent.

1.3.7 Communication

1.3.7.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the engines are normally controlled: one of these is to be an engine-room telegraph which provides visual indication of the orders and responses both in the machinery space and in the navigation bridge. Appropriate means of communication is to be provided from the navigation bridge and the engine-room to any other positions from which the speed of direction of thrust of the propellers may be controlled.

1.3.8 Accessibility

1.3.8.1 Accessibility, for the purposes of control, maintenance, inspection and repair of various machinery and equipment, is to be provided in machinery and boiler spaces.

1.3.9 Stuffing boxes for shaftings

1.3.9.1 Stuffing boxes are to be fitted on the watertight bulkhead of the engine room where the shafts pass through. They are to be so arranged as to be convenient for tightening and renewing the packings from the engine room side. The fore sealing ends of the stern tubes as well as the plummer blocks are to be easily accessible for maintenance.

1.3.10 Earthing

1.3.10.1 Suitable earthing arrangements are to be provided to prevent excessive electrical potential difference between the crankshaft/shafting of main propulsion diesel engines and hull.

CHAPTER 2 PUMPING AND PIPING SYSTEMS

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 Unless otherwise stated, this Chapter applies to piping systems of all ships. Chemical cargo piping, chemical process piping, liquefied gases cargo piping and liquefied gases process piping are to comply with relevant requirements in ISC Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk and ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk respectively.

2.1.1.2 The certification requirements and product survey of pumps, pipes, valves and fittings in piping systems are to comply with the relevant requirements specified in Chapter 3 of PART ONE of the Rules.

2.1.2 Plans and documents

2.1.2.1 For all ships, the following plans and documents are to be submitted for approval:

(1) arrangement of machinery and boiler spaces;
(2) bilge piping and ballast piping;
(3) arrangement of air pipes, sounding pipes and overflow pipes;
(4) fuel oil feeding system for main and auxiliary engines and boilers;
(5) fuel oil transfer system;
(6) lubricating oil piping for main and auxiliary engines;
(7) cooling water piping system for main and auxiliary engines;
(8) compressed air piping system;
(9) steam piping;
(10) condensate and exhaust steam piping;
(11) boiler feed and blow-off piping;
(12) oil fuel heating piping;
(13) purgative system for fuel oil and lubricating oil;
(14) exhaust gas piping for main and auxiliary engines;
(15) arrangement of ventilation pipes for engine room;
(16) hydraulic systems;
(17) arrangement of drain pipes;
(18) additional plans and documents as may be deemed necessary by ISC.

2.1.2.2 For oil tankers, the following plans and documents are to additionally be submitted for approval:

(1) cargo oil piping system;
(2) bilge piping system of cargo pump rooms and cofferdams;
(3) cargo oil heating piping;
(4) arrangement of venting systems (including purge, gas-free systems);
(5) closed ullage system (where applied);
(6) arrangement of cargo pump tank.

2.1.2.3 For all ships, the following plans and documents are to be submitted for information (if relevant information is reflected in the submitted plans, submission of following plans and documents is not necessary):

(1) specifications of machinery installations;
(2) particulars of machinery equipment;
(3) calculations of machinery equipment.

2.1.2.4 The materials, sizes, types, design pressures and design temperatures of pipes, valves and fittings, and the set pressure of safety valves are to be clearly marked on plans. Where separate calculations are not submitted, necessary rule calculations are to be affixed to the plans.

2.1.3 Design pressure

2.1.3.1 The design pressure for piping is the maximum permissible working pressure and it is not to be less than the highest set pressure of any safety valve or relief valve.

2.1.3.2 For pipes containing fuel oil, the design pressure is to be taken as given in Table 2.1.3.2.

Design pressure for pipes containing fuel oil **Table 2.1.3.2**

Working temperature / Working pressure	T ≤ 60℃	T > 60℃
P ≤ 0.7 MPa	0.3 MPa or highest working pressure, whichever is greater	0.3 MPa or highest working pressure, whichever is greater
P > 0.7 MPa	Highest working pressure	1.4 MPa or highest working pressure, whichever is greater

2.1.3.3 For special cases, the design pressure is to be specially considered.

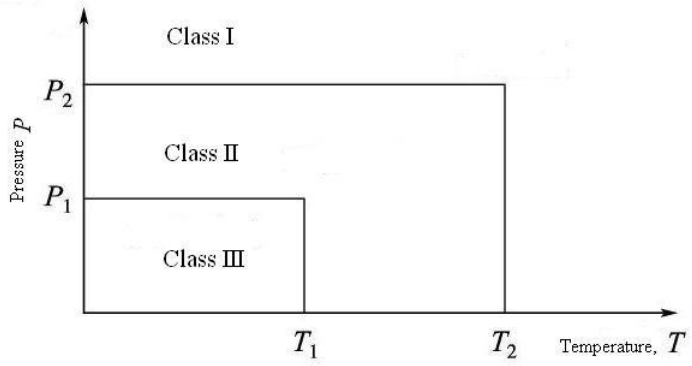
2.1.4 Design temperature

2.1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid.
In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15℃ above the designed temperature are expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess. For special cases, the design temperature is to be specially considered.

2.1.5 Classes of pipes

2.1.5.1 For the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure, pressure piping systems are divided into three classes in accordance with their design pressure and design temperature, as indicated in Table 2.1.5.1.

Piping system class **Table 2.1.5.1**



Piping system	Class I		Class II		Class III	
	Design pressure > P_2 (MPa)	Design temperature > T_2 (℃)	Design pressure ≤ P_2 (MPa)	Design temperature ≤ T_2 (℃)	Design pressure ≤ P_1 (MPa)	Design temperature ≤ T_1 (℃)
Steam	> 1.6	or > 300	≤ 1.6	and ≤ 300	≤ 0.7	and ≤ 170
Thermal oil	> 1.6	or > 300	≤ 1.6	and ≤ 300	≤ 0.7	and ≤ 150
Fuel oil, lub-oil, flammable hydraulic oil	> 1.6	or > 150	≤ 1.6	and ≤ 150	≤ 0.7	and ≤ 60
Other media	> 4.0	or > 300	≤ 4.0	and ≤ 300	≤ 1.6	and ≤ 200

Notes:

① For Class I piping, one parameter for design pressure and design temperature of Class I specified in the Table is to be met; For Class II piping, one parameter for design pressure and design temperature of Class II specified in the Table is to be met; For Class III piping, two parameters are not to exceed the provisions of Class III the Table.

② Toxic or corrosive media, flammable media heated above flash point or with flash point below 60℃ media and liquefied gas belong to class I. If means of special safeguards for preventing leakage and its consequences are provided (e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening etc.), they may also belong to class II, but except toxic media.

③ Cargo pipes belong to class III.

④ Class III pipes may be used for open ended piping, e.g. drains, overflows, vents boiler waste steam pipes, etc.

⑤ Other media mean air, gases, water, and non-flammable hydraulic oil.

⑥ Thermal oil means the circulating oil used in the thermal oil system as specified in Section 8, Chapter 4 of this PART.

2.1.6 Materials

2.1.6.1 Materials to be used for pipes, valves and fittings are to be suitable for the medium and service for which the piping is intended. In the case of especially corrosive media, the material for the piping system is to be taken into consideration in each particular case.

2.1.6.2 Material for pipes, valves and relative fittings belonging to Classes I and II and for valves and pipes fitted on the ship's side and for valves fitted on the collision bulkhead are to be tested in accordance with the relevant requirements of ISC Rules for Materials and Welding.

2.1.6.3 Materials for pipes, valves and fittings of Class III are to be tested in accordance with applicable standards.

Section 2 CARBON, LOW ALLOY STEELS AND stainless steels

2.2.1 Carbon and low alloy steel pipes, valves and fittings

2.2.1.1 Classes I and II pipes are to be seamless steel pipes or welded pipes fabricated with a welding procedure approved by ISC.

2.2.1.2 In general, carbon and carbon-manganese steel pipes, valves and fittings are not to be used for medium temperatures above 400℃. Nevertheless, they may be used for higher temperatures if their metallurgical behavior and time dependent strength (UTS after 100,000 h) are in compliance with national or international codes or standards and if such values are guaranteed by the steel manufacturer.

Special alloy steel pipes, valve and fittings are to be employed according to the relevant requirements of ISC Rules for Materials and Welding.

2.2.2 Calculation of wall thickness

2.2.2.1 The minimum wall thickness $\delta$of steel pipes subject to internal pressure is not to be less than that determined by the following formula①:

$$\delta = \delta_0 + b + c \quad \text{mm}$$

where: δ_0 — the basic wall thickness, in mm, see 2.2.2.2 of this Section;

b — allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.2.2.3 of this Section;

c — corrosion allowance, in mm, to be obtained from Table 2.2.2.1.

Corrosion allowance *C* for steel pipes **Table 2.2.2.1**

Usage of piping	*C*	Usage of piping	*C*
Overheat steam piping	0.3	Lubricating oil piping	0.3
Saturated steam piping	0.8	Fuel oil piping	1.0
Steam heating piping in cargo tank	2.0	Cargo oil piping	2.0
Boiler open-type feed piping	1.5	Refrigerant piping of refrigerating installation	0.3
Boiler close-type feed piping	0.5	Fresh water piping	0.8
Boiler blow-off piping	1.5	Sea water piping	3.0
Compressed air piping	1.0	Salt water piping in refrigerated hold	2.0
Hydraulic oil piping	0.3		

For pipes passing through tanks, an additional corrosion allowance is to be taken, depending on the external medium, in order to account for the external corrosion. Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the corrosion allowance may be reduced by not more than 50%. In the case of use of special alloy steel with sufficient corrosion resistance, the corrosion allowance may be reduced, even to zero.

2.2.2.2 The basic wall thickness δ_0 for steel pipes is to be determined by the following formula:

$$\delta_0 = \frac{pD}{2[\sigma]e + p} \quad \text{mm}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter;

D — outside diameter of steel pipes, in mm;

① The formula applies to pipes where the ratio outside-diameter to inside-diameter does not exceed the value 1.7.

[σ] — permissible stress of steel pipes, in N/mm^2, see 2.2.2.4 of this Section;

e — welding efficiency factor. For seamless steel pipes and electric resistance or induction welded steel pipes, e is to be taken as 1; for pipes made by other methods, e will be specially considered.

2.2.2.3 Bending allowance b is not to be less than that determined by the following formula:

$$b = 0.4 \frac{D}{R} \delta_0 \quad \text{mm}$$

where: R — radius of curvature of a pipe bend at the centre line of the pipe, in mm, in general, R is not to be less than 3D;

D — outside diameter of steel pipes, in mm;

δ_0 — basic wall thickness, in mm, see 2.2.2.2 of this Section.

2.2.2.4 Permissible stress [σ] of steel pipes is to be taken as the lowest of the following values:

$$[\sigma] = \frac{R_m}{2.7} \quad \text{N/mm}^2$$

$$[\sigma] = \frac{R_{eH}^T}{1.6} \quad \text{N/mm}^2$$

$$[\sigma] = \frac{\sigma_D^T}{1.6} \quad \text{N/mm}^2$$

$$[\sigma] = \sigma_c^T \quad \text{N/mm}^2$$

where: R_m — tensile strength of material at room temperature, in N/mm^2;

R_{eH}^T — yield stress or 0.2% proof stress ($R_{p0.2}$) of material at design temperature, in N/mm^2;

σ_D^T — average stress of material to produce rupture in 100,000 h at design temperature, in N/mm^2;

σ_c^T — average stress to produce 1% creep in 100,000 h at the design temperature, in N/mm^2;

R_m, R_{eH}^T, σ_D^T are to comply with the relevant requirements of ISC Rules for Materials and Welding. National or international standards may be accepted for R_{eH}^T. σ_c^T may be used as appropriate based on reliable conditions if it is deemed necessary.

2.2.2.5 The minimum wall thickness δ mentioned in 2.2.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness δ_m of pipes is not to be less than that determined by the following formula:

$$\delta_m = \frac{\delta}{1 - \frac{a}{100}} \quad \text{mm}$$

where: a — percentage of negative manufacturing tolerance on thickness.

2.2.2.6 Where the minimum thickness calculated by the formula specified in 2.2.2.5 is less than that shown in Table 2.2.2.6(1), Table 2.2.2.6(2) or Table 2.2.2.6(3), the minimum nominal thickness for the appropriate standard pipe size shown in the Tables is to be used.

For threaded pipes, the thickness is to be measured at the bottom of the thread.

External diameter and minimum nominal thickness for steel pipes, in mm Table 2.2.2.6(1)

External diameter, *D*	Minimum nominal thickness (δ)			
	General pipe③④⑥⑧⑨⑩	Air pipe, overflow pipe and sounding pipe of tank related to hull structure①②③④⑥⑦⑧	Bilge and ballast pipe, general sea water pipe and steam heating coil in liquid tank①③④⑤⑥⑦⑧	Bilge pipe, air pipe, overflow pipe and sounding pipe through ballast tank and fuel oil tank. Ballast pipe through fuel oil tank and fuel oil pipe through ballast tank①②③④⑤⑥⑦⑧
10.2~12	1.6			
13.5~19.3	1.8			
20	2.0			
21.3~25	2.0		3.2	
26.9~33.7	2.0		3.2	
38~44.5	2.0	4.5	3.6	6.3
48.3	2.3	4.5	3.6	6.3
51~63.5	2.3	4.5	4.0	6.3
70	2.6	4.5	4.0	6.3
76.1~82.5	2.6	4.5	4.5	6.3
88.9~108	2.9	4.5	4.5	7.1
114.3~127	3.2	4.5	4.5	8.0
133~139.7	3.6	4.5	4.5	8.0
152.4~168.3	4.0	4.5	4.5	8.8
177.8	4.5	5.0	5.0	8.8
193.7	4.5	5.4	5.4	8.8
219.1	4.5	5.9	5.9	8.8
244.5~273	5.0	6.3	6.3	8.8
298.5~368	5.6	6.3	6.3	8.8
406.4~457	6.3	6.3	6.3	8.8

Notes:

① Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the minimum wall thickness may be reduced by an amount up to 1 mm.

② For sounding pipes, except those for cargo tanks with cargo having a flash point less than 60℃, the minimum wall thickness is intended to apply to the part outside the tank.

③ For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.

④ The external diameters and thicknesses have been selected from ISO Recommendations R336 for welded and seamless steel pipes. For pipes covered by other Standards, slightly reduced thicknesses may be accepted.

⑤ The minimum wall thickness for bilge lines and ballast lines through deep tanks will be subject to special consideration. The minimum wall thickness for ballast lines through cargo tanks is not to be less than that specified in Table 5.3.4.2 of Section 3, Chapter 5 of this PART.

⑥ The minimum wall thickness for pipes larger than 457 mm nominal size is to be in accordance with a national or international standard and in any case not less than the minimum wall thickness of the appropriate column indicated for 406.4 to 457 mm pipe size in Table 2.2.2.6(1).

⑦ The minimum internal diameters of bilge, sounding, air and overflow pipes are to be:

Bilge 50 mm
Sounding 32 mm
Air and overflow 50 mm

⑧ In general, the minimum thickness listed in this Table is the nominal wall thickness and no allowance need be made for negative tolerance and reduction in thickness due to bending.

⑨ The minimum wall thickness of exhaust gas pipe will be subject to special consideration.

⑩ The minimum wall thickness for cargo oil lines will be subject to special consideration.

External diameter and minimum nominal thickness δ for stainless steel pipes, in mm **Table2.2.2.6(2)**

External diameter (D)	Minimum nominal thickness (δ)
≤10	1.0
11~18	1.5
19~83	2.0
84~169	2.5
170~246	3.0
247~340	3.5
341~426	4.0
427~511	4.5
512~597	5.0

External Diameter and Minimum Nominal Wall Thickness for Austenitic Stainless Steel Pipes, in mm **Table 2.2.2.6(3)**

External diameter (D)	Minimum nominal wall thickness (δ)
10.2 ~ 17.2	1.0
21.3 ~ 48.3	1.6
60.3 ~ 88.9	2.0
114.3 ~ 168.3	2.3
219.1	2.6
273.0	2.9
323.9 ~ 406.4	3.6
> 406.4	4.0

Note: Diameters and thicknesses according to national or international standards may be accepted.

2.2.2.7 The minimum wall thickness of the scuppers and discharge pipes is to comply with the relevant requirements of regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.2.2.8 The minimum wall thickness of air pipes above the weather deck is to comply with the relevant requirements of 1.12.7.5 of PART TWO of the Rules.

Section 3 COPPER AND COPPER ALLOYS

2.3.1 Copper and copper alloy pipes, valves and fittings

2.3.1.1 Copper and copper alloy pipes used in Classes I and II piping systems are to be seamless.

2.3.1.2 Materials of copper and copper alloys for Class III piping systems are to be manufactured and tested in accordance with the approved standards.

2.3.1.3 In general, copper and copper alloy pipes, valves and fittings are not be used for media having a temperature above the following limits:

copper and aluminum brass: 200℃;

copper nickel: 300℃;

special bronze suitable for high temperature services: 260℃.

2.3.2 Calculation of wall thickness

2.3.2.1 The minimum wall thickness δ of copper and copper alloy pipes subject to internal pressure is not to be less than that determined by the following formula①:

$$\delta = \delta_0 + b + c \quad \text{mm}$$

where: δ_0 — the basic wall thickness, in mm, see 2.3.2.2 of this Section;

b — allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.3.2.3 of this Section;

c — corrosion allowance, in mm; for copper, brass and similar alloys, copper-tin alloys except those with lead contents, and copper-nickel alloys where the nickel content is less than 10%, c = 0.8 mm; copper-nickel alloys where the nickel content is 10% or greater, c = 0.5

① The formula applies to pipes where the ratio outside-diameter to inside-diameter does not exceed the value 1.7.

mm; where the media are non-corrosive relative to the pipe material, $c = 0$.

2.3.2.2 The basic wall thickness of copper and copper alloy pipes is to be determined by the following formula:

$$\delta_0 = \frac{pD}{2[\sigma]e + p} \quad \text{mm}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter;
D — outside diameter of pipe, in mm;
$[\sigma]$ — permissible stress, in N/mm^2, obtained from Table 2.3.2.2;
e — efficiency factor, $e = 1$ for seamless copper pipes and for welded copper pipes delivered by manufacturers approved for making welded copper pipes which are considered an equivalent to seamless copper pipes. For copper pipes made by other methods, e will be specially considered.

Allowable stress of copper and copper alloy pipes [σ] **Table 2.3.2.2**

Materials	Material condition	Tensile strength (N/mm^2)	Allowable stress (N/mm^2)										
			Design temperature (℃)										
			50	75	100	125	150	175	200	225	250	275	300
copper	annealing	215	41	41	40	40	34	27.5	18.5	—	—	—	—
Aluminum brass	annealing	325	78	78	78	78	78	51	24.5	—	—	—	—
copper-nickel alloys CuNi5Fe1Mn CuNi10Fe1Mn	annealing	275	68	68	67	65.5	64	62	59	56	52	48	44
copper-nickel alloys CuNi30	annealing	365	81	79	77	75	73	71	69	67	65.5	64	62

Notes:
① If the metal temperature is between the values listed in the Table, allowable stress may be determined by linear interpolation.
② The allowable stresses of materials not covered by the Table are to submit detailed information.

2.3.2.3 Bending allowance b is not to be less than that determined by the following formula:

$$b = 0.4\frac{D}{R}\delta_0 \quad \text{mm}$$

where: R — radius of curvature of a pipe bend at the centre line of the pipe, in mm. In general, R is not to be less than $3D$;
D — outside diameter of pipe, in mm;
δ_0 — basic wall thickness, in mm, see 2.3.2.2 of this Section.

2.3.2.4 The minimum wall thickness δ mentioned in 2.3.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness of pipes is not to be less than that determined by the following formula:

$$\delta_m = \frac{\delta}{1 - \frac{a}{100}} \quad \text{mm}$$

where: a — percentage of negative manufacturing tolerance on thickness.

2.3.2.5 Where the minimum wall thickness calculated by the formula specified in 2.3.2.4 is less than that shown in Table 2.3.2.5, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used.
For threaded pipes, the thickness is to be measured at the bottom of the thread.

External diameter and minimum nominal thickness δ_m for copper and copper alloy pipes, in mm **Table 2.3.2.5**

Outside diameter (D)	Minimum nominal thickness (δ_m)	
	Copper	Copper alloys
8~10	1.0	0.8
12~20	1.2	1.0
25~44.5	1.5	1.2
50~76.1	2.0	1.5
88.9～108	2.5	2.0
133～159	3.0	2.5

Outside diameter (D)	Minimum nominal thickness (δ_m)	
	Copper	Copper alloys
193.7～267	3.5	3.0
273～470	4.0	3.5
508	4.5	4.0

Notes:
① The outside diameters and the thickness have been selected from ISO Standards.
② For pipes covered by other standards, slightly reduced thickness may be accepted.

Section 4 OTHER MATERIALS

2.4.1 Grey cast iron pipes, valves and fittings

2.4.1.1 Grey cast iron pipes, valves and fittings are not to be used in Class I and Class II piping systems. Grey cast iron valves and fittings may be used in Class II steam piping but the design temperature does not exceed 220℃.

2.4.1.2 Grey cast iron pipes, valves and fittings may, in general, be accepted in Class III piping systems, in cargo lines within cargo tanks of tankers , but grey cast iron is not to be used for the following:

(1) cargo oil pipelines having pressures exceeding 1.6 MPa on weather decks of oil tankers;
(2) pipes, valves and fittings intended for conveying media having temperatures above 220℃;
(3) piping may be subjected to pressure shock, excessive strains and vibration;
(4) ship-side valves and fittings and sea valves, pipes fitted on the ship sides and sea chest;
(5) valves fitted on the collision bulkhead;
(6) valves under static head fitted on the outside of fuel tank walls;
(7) boiler blow-off systems;
(8) pipes for steam, fire extinguishing, bilge and ballast systems.

Grey cast iron may be accepted for pressures up to 1.6 MPa for cargo oil pipe lines on weather decks of oil tankers except for manifolds and their valves and fittings connected to cargo handling hoses.

2.4.2 Nodular graphite cast iron pipes, valves and fittings

2.4.2.1 Ferritic nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12% on a gauge length of $5.65\sqrt{S_0}$, where S_0 is the cross-sectional area of the test piece.

2.4.2.2 Ferritic nodular graphite iron pipes, valves and fittings may be accepted for bilge, ballast and cargo oil piping.

2.4.2.3 Ferritic nodular graphite cast iron pipes, valves and fittings are not to be used in piping systems for conveying media having temperatures exceeding 350℃.

2.4.2.4 Where ferritic nodular graphite iron castings are used for ship-side pipes, valves and fittings, the properties of this material are to comply with the relevant requirements of ISC Rules for Materials and Welding.

2.4.2.5 Where the elongation is less than the minimum required in 2.4.2.1 of this Section, the material is to be subject to the same limitations as grey cast iron.

2.4.3 Plastic pipes

2.4.3.1 The ranges and locations of plastic pipes used in ships are to comply with the provisions in Table 1 of Appendix I, and the plastic pipes are to comply with the fire endurance requirements in the Table.

2.4.3.2 Plastic pipes used on ships are to be selected in relation to their chemical composition, physical and mechanical properties, and temperature limits.

2.4.3.3 Plastic pipes are in general not to be used for media with a temperature above 60℃ or below 0℃.

2.4.3.4 Plastic pipes used on ships are to be designed, manufactured, used and test in accordance with the relevant requirements in Appendix 1 of this Chapter.

2.4.4 Flexible hoses

2.4.4.1 Flexible hoses mean short length of metallic or non-metallic hoses normally with prefabricated end fittings ready for installation.

2.4.4.2 Flexible hoses may be used for a permanent connection between a fixed piping system and items of machinery, as well as temporary connection between portable equipment and pipes.

2.4.4.3 Flexible hoses are to be designed, manufactured, used and tested in accordance with the relevant

requirements of Appendix 2 of this Chapter.

Section 5 CONNECTION OF PIPE LENGTHS, HEAT TREATMENT AND NON-DESTRUCTIVE TESTING

2.5.1 Connection of pipe lengths

2.5.1.1 Direct connection of pipe lengths may be obtained by:

(1) welded butt-joints between pipes or between pipes and valve chests or other fittings, the welded butt-joints are to be of full penetration type with or without special provisions for the quality of root side①;
(2) slip-on sleeve welded joints, the slip-on sleeve welded joints are to have sleeves and relative welding of adequate dimensions conforming to the recognized standard;
(3) threaded sleeve joints of approved type;
(4) mechanical joints.

2.5.1.2 The application of the aforesaid types of connection is as follows:

(1) Welded butt-joints and slip-on sleeve welded joints are to comply with the requirements specified in Table 2.5.1.2(1).

Connection of pipe length **Table 2.5.1.2(1)**

Type of connection	Allowed for classes	Allowed for outside diameter
Butt welded joints with special provision for a high quality of root side	I, II, III	No restriction
Butt welded joints without special provision for a high quality of root side	II, III	
Slip-on sleeve welded joints	III	
	I, II, except for piping systems conveying toxic media where fatigue, severe erosion is expected to occur	$D \leq 88.9$ mm

(2) Slip-on threaded joints are to comply with requirements of a recognized standard. Slip-on threaded joints may be used for outside diameters as stated below except for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice is expected to occur. Threaded joints in CO_2 systems are to be allowed only inside protected spaces and in CO_2 cylinder rooms.

① Threaded joints for direct connectors of pipe lengths with tapered thread may be allowed for Class I, outside diameter not more than 33.7 mm as well as Class II and Class III, outside diameter not more than 60.3 mm.

② Threaded joints for parallel thread may be allowed for Class III, outside diameter not more than 60.3 mm.

③ In particular cases, sizes in excess of those mentioned above may be accepted if they satisfy the requirements of recognized international or national standards.

2.5.2 Flange connections

2.5.2.1 Typical flange connections are indicated in Figure 2.5.2.1.

Slip-on joints, sleeve threaded joints and other types of direct connection of pipe lengths (e.g. bell and spigot joints) may be allowed in each particular case for small diameter and depending upon the service conditions.

2.5.2.2 The above-mentioned types of flange connections are to be selected in accordance with the requirements specified in Table 2.5.2.2.

Application of typical flange connections **Table 2.5.2.2**

Piping class	Toxic or corrosive media④, flammable media④, liquefied gas	Lubricating oil and fuel oil	Steam③ and hot oil	Other media①②③
I	A,B⑥	A,B	A,B⑥	A,B
II	A,B,C	A,B,C,E⑦	A,B,C,D⑤,E⑤	

① The expression "special provisions for the quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by ISC.

III		A,B,C,E	A,B,C,D,E	A,B,C,D,E,F②

Notes:
① Including water, air, other gases, hydraulic oil.
② Type F for water pipes and open ended lines only.
③ Only type A when design temperature exceeds 400℃.
④ Only type A when design pressure exceeds 1 MPa.
⑤ Types D and E are not be used when design temperature exceeds 250℃.
⑥ Type B for outside diameter < 150 mm only.
⑦ Type E for oil piping when design temperature < 150℃ and design pressure < 1.6 MPa only.

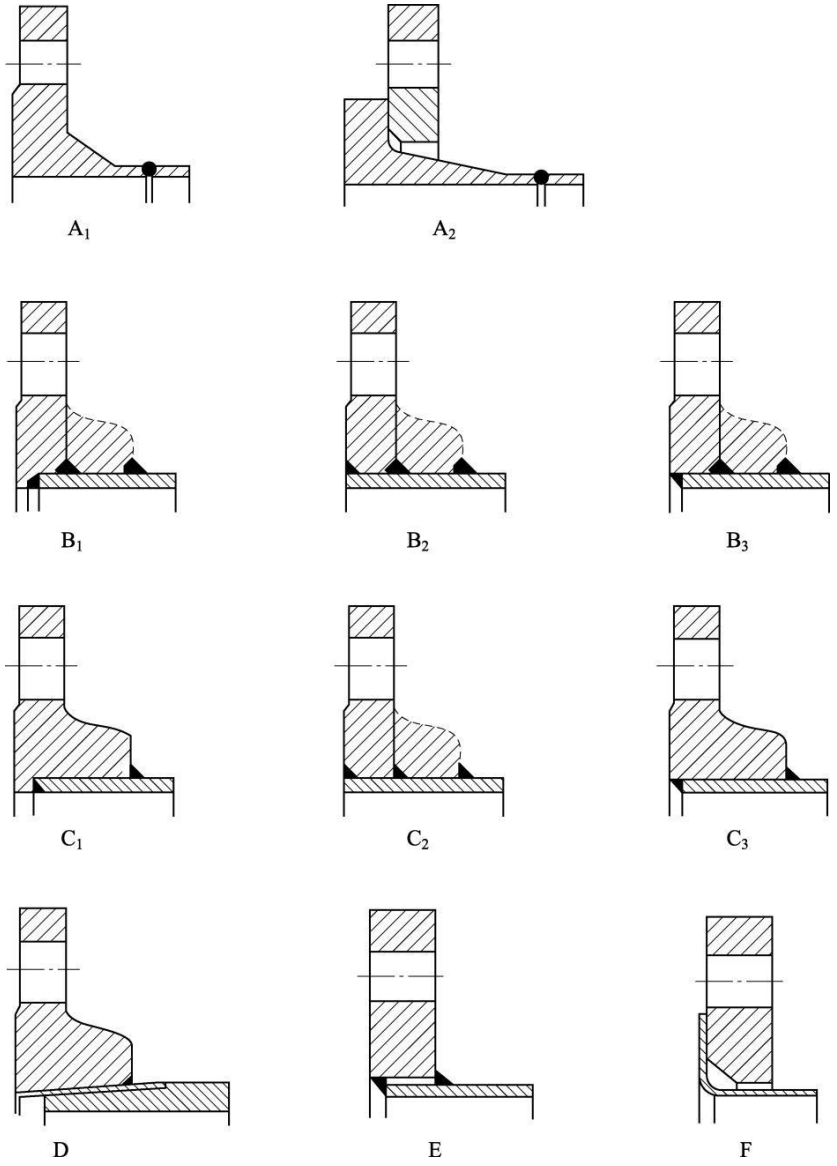


Figure 2.5.2.1 Typical flange connections

Notes: ① For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. After the flange has been screwed hard home, the pipe is to be expanded into the flange.
② The leg length of the fillet weld and the penetration of the flange edge, as shown in the Figure, are in general to be 1.5 times the wall thickness of the pipe, but not less than 5 mm.

2.5.2.3 The dimensions of flanges and relative bolts are to be chosen in accordance with the national standards or acceptable standards. For special application, the dimensions of flanges and relative bolts are to be subject to special consideration①.

① For special applications where the fitting temperature, pressure and size of the flange exceed reliable limits, a complete

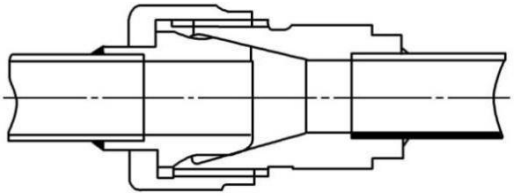
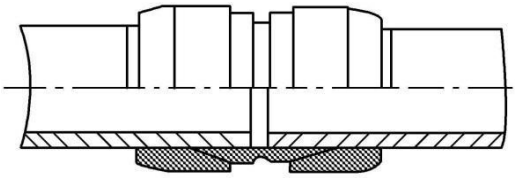
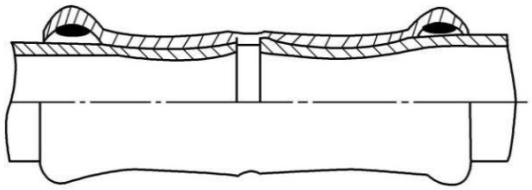
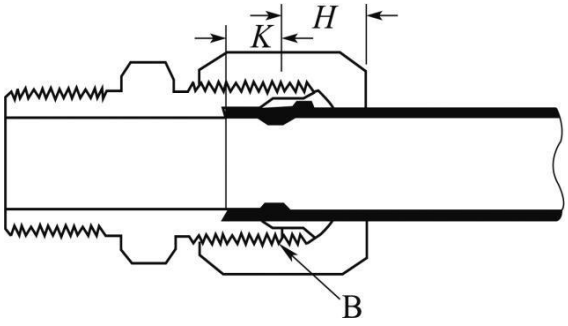
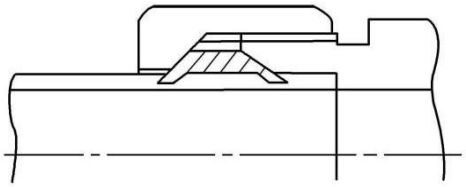
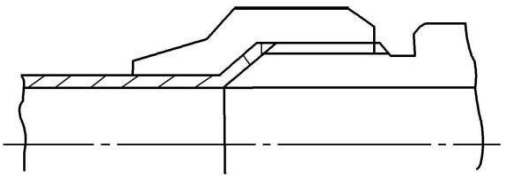
Gaskets are to be suitable for the media being conveyed under design pressure and temperature conditions and their dimensions and configuration are to be in accordance with national or acceptable standards.
Flange connections are to be in accordance with national or international standards that are applicable to the piping system and are to recognize the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

2.5.3 Mechanical joints

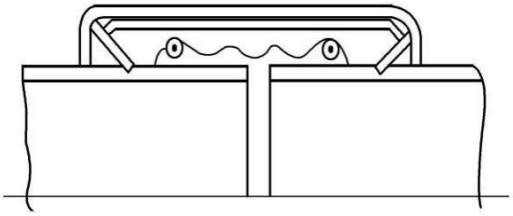
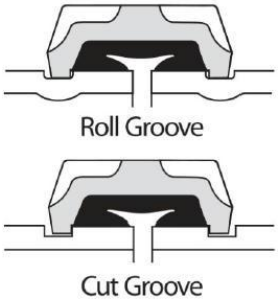
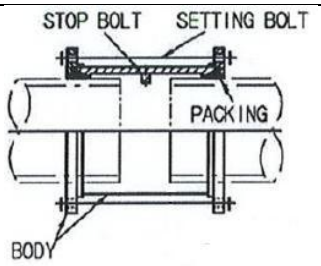
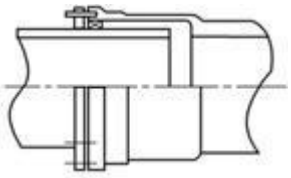
2.5.3.1 The different mechanical joints applicable to this paragraph are indicated in Table 2.5.3.1(1). The mechanical joints are to be subject to type approval based on different usage and location in accordance with the requirements of Appendix 3 of this Chapter.
2.5.3.2 Where appropriate, mechanical joints are to be of fire resistant type as required by Table 2.5.3.1(2). Fire endurance test is specified in 1.5.5(6), Appendix 3 of this Chapter.
2.5.3.3 Material of mechanical joints is to be compatible with the piping material and internal and external media.
2.5.3.4 Application of mechanical joints and their acceptable use for each service is indicated in Table 2.5.3.1(2); dependence upon the Class of piping and pipe dimensions is indicated in Table 2.5.3.1(3).
In particular cases, sizes in excess of those mentioned above may be accepted if in compliance with a recognized national and/or international standard.
2.5.3.5 Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.
2.5.3.6 Mechanical joints, which in the event of damage could cause flooding or fire, are not to be used in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships (or freeboard deck of cargo ships) or tanks containing flammable fluids. The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints conforming to recognized standards are to be used.
2.5.3.7 Mechanical joints in bilge systems of machinery space and higher fire risk space (e.g. cargo pump room and vehicle space) are to be of fire resistant type. For the required fire resistant mechanical joints, see Table 2.5.3.1(2).
2.5.3.8 Mechanical joints are to be tested where applicable, to a burst pressure of 4 times the design pressure. When the design pressure exceeds 20 MPa, the burst pressure will be specially considered.
2.5.3.9 Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.
2.5.3.10 Slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces which are not easily accessible (refer to MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media.
Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.
2.5.3.11 Mechanical joints are not to be used in the following cases:
(1) bilge piping through ballast tanks and fuel tanks;
(2) sea water and ballast piping (including air and overflow pipes) through cargo holds and fuel tanks;
(3) fuel and oil piping (including air and overflow pipes) through machinery spaces, cargo holds and ballast tanks.
2.5.3.12 The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

calculation is to be carried out for bolts and flanges.

Examples of mechanical joints **Table 2.5.3.1(1)**

Pipe unions	
Welded and brazed types	
Compression	
Swage type	
Press type	
Typical Compression Type①	
Bite type	
Flared type	

① This requirement is applicable to any mechanical pipe joints submitted for approval from 1 January 2020 and to any renewal of type approval of existing design of mechanical pipe joint after 1 January 2020.

Slip-on joints	
Grip type	
Machine grooved type	
Slip type	  

Application of mechanical joints **Table 2.5.3.1(2)**

Systems		Kind of connections				
		Pipe Unions	Compression Couplings	Slip-on Joints	Classification of pipe system	Fire endurance test condition⑦
Flammable fluids (Flash point ≤ 60°C)						
1	Cargo oil lines①	×	×	×	dry	30 min dry (*)
2	Crude oil washing lines①	×	×	×	dry	
3	Vent lines③	×	×	×	dry	
Inert gas						
4	Water seal effluent lines	×	×	×	wet	30 min wet (*)
5	Scrubber effluent lines	×	×	×	wet	30 min wet (*)
6	Main lines①②	×	×	×	dry	30 min dry (*)
7	Distributions lines①	×	×	×	dry	30 min dry (*)
Flammable fluids (Flash point > 60°C)						

8	Cargo oil lines[①]	×	×	×	dry	30 min dry (*)
9	Fuel oil lines[②③]	×	×	×	wet	30 min wet (*)
10	Lubricating oil lines[②③]	×	×	×	wet	
11	Hydraulic oil[②③]	×	×	×	wet	
12	Thermal oil[②③]	×	×	×	wet	
Sea Water						
13	Bilge lines[④]	×	×	×	dry/wet	8 min dry + 22 min wet (*)
14	Permanent water filled fire extinguishing systems, e.g. fire main, sprinkler systems[③]	×	×	×	wet	30 min wet (*)
15	Non-permanent water filled fire extinguishing systems, e.g. foam, drencher systems and fire main[③]	×	×	×	dry/wet	8 min dry + 22 min wet (*) For foam systems FSS Code Chapter 6 to be observed
16	Ballast system[④]	×	×	×	wet	30 min wet (*)
17	Cooling water system[④]	×	×	×	wet	30 min wet (*)
18	Tank cleaning services	×	×	×	dry	Fire endurance test not required
19	Non-essential systems	×	×	×	dry dry/wet wet	Fire endurance test not required
Fresh Water						
20	Cooling water system[④]	×	×	×	wet	30 min wet (*)
21	Condensate return[④]	×	×	×	wet	30 min wet (*)
22	Non-essential system	×	×	×	dry dry/wet wet	Fire endurance test not required
Sanitary/Drains/Scuppers						
23	Deck drains (internal)[⑤]	×	×	×	dry	Fire endurance test not required
24	Sanitary drains	×	×	×	dry	
25	Scuppers and discharge (overboard)	×	×	-	dry	
Sounding/Vent						
26	Water tanks/Dry spaces	×	×	×	dry, wet	Fire endurance test not required
27	Oil tanks (f.p.>60℃) [②③]	×	×	×	dry	
Miscellaneous						
28	Starting/Control air[④]	×	×	-	dry	30 min dry (*)
29	Service air (non-essential)	×	×	×	dry	Fire endurance test not required
30	Brine	×	×	×	wet	
31	CO_2 system (outside protected space)	×	×	-	dry	30 min dry (*)
32	CO_2 system (inside protected space)	×	×	-	dry	Mechanical joints shall be constructed of materials with melting point above 925℃. Ref. to FSS Code Chapter 5.
33	Steam	×	×	×[⑥]	wet	Fire endurance test not required

Notes:
× Application is allowed.
– Application is not allowed.
∗ Fire endurance test as specified in 1.5.5(6) of Appendix 3 of this Chapter.
Fire resistance capability:
If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes are to be observed:
① Fire endurance test shall be applied when mechanical joints are installed in pump rooms and open decks.
② Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
③ Approved fire resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS Reg. II-2/9.2.3.3.2.2(10) and not used for fuel oil lines.
④ Fire endurance test shall be applied when mechanical joints are installed inside machinery spaces of category A.
General:
⑤ Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.
⑥ Slip type slip-on joints as shown in Table 2.5.3.1(1) may be used for pipes on deck with a design pressure of 10 bar or less.
⑦ If a connection has passed the "30 min dry" test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

Application of mechanical joints depending upon the class of piping Table 2.5.3.1(3)

Types of joints	Classes of piping system		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	× (D_0≤ 60.3 mm)	× (D_0≤ 60.3 mm)	×
Compression couplings			
Swage type	×	×	×
Bite typ	× (D_0≤ 60.3 mm)	× (D_0≤ 60.3 mm)	×
Typical Compression Type①	× (D_0≤ 60.3 mm)	× (D_0≤ 60.3 mm)	×
Flared type	× (D_0≤ 60.3 mm)	× (D_0≤ 60.3 mm)	×
Press type	–	–	×
Slip-on joints			
Machine grooved type	×	×	×
Grip type	–	×	×
Slip type	–	×	×

Notes:
× Application is allowed.
– Application is not allowed.
D_0 Outside diameter of the pipe.

2.5.4 Heat treatment and non-destructive testing

2.5.4.1 The heat treatment and non-destructive testing of piping systems are to comply with the relevant requirements of ISC Rules for Materials and Welding.

Section 6 PUMPS, VALVES AND FITTINGS

2.6.1 Pumps

2.6.1.1 Pumps are to be designed and manufactured according to accepted standards.

2.6.1.2 Hydraulic tests

All components of pumps subject to pressure are to be subject to hydraulic tests in workshop prior to assembly. The hydraulic test pressure is to be 1.5 times the design pressure, but need not exceed the design pressure plus 7 MPa.

For centrifugal pumps, the design pressure is to be taken as the maximum pressure head on the performance curve. For displacement pumps, the design pressure is to be taken as the relief valve setting pressure.

For steam driven pumps, the test pressure at the steam side is to be 1.5 times the steam working pressure.

---

① This requirement is applicable to any mechanical pipe joints submitted for approval from 1 January 2020 and to any renewal of type approval of existing design of mechanical pipe joint after 1 January 2020.

2.6.1.3 Capacity tests

Pump capacities are to be checked with the pump operating at design conditions (rated speed and pressure head). For centrifugal pumps, the pump characteristic (head-capacity) design curve is to be verified to the satisfaction of the Surveyor.

Capacity tests may be waived if previous satisfactory tests have been carried out on similar pumps.

2.6.1.4 Relief valve capacity test

For positive displacement pumps with an integrated relief valve, the valve's setting and full flow capacity corresponding to the pump maximum rating is to be verified.

The operational test for relief valve capacity may be waived if previous satisfactory tests have been carried out on similar pumps.

2.6.2 Valves and fittings

2.6.2.1 Valves are to be designed and manufactured according to accepted standards. For other structurally new-type valves or non-standard valves, detailed drawings and information are to be submitted.

2.6.2.2 The strength of valves and fittings in piping system is to be appropriate to the strength required by the connected pipes and is to be able to work efficiently under the maximum working pressure. Valves are to be made of steel, cast iron, copper, copper alloy or other materials suitable for the intended service.

2.6.2.3 All valves are to be so constructed as to prevent the possibility of valve bonnets or glands being slackened back or loosened when the valves are operated. Screwed-on valve bonnets are not to be used for valves with nominal diameter exceeding 40 mm in Class I and Class II piping systems, sea valves, ship-side valves and valves in flammable liquid system.

2.6.2.4 Valves on board ships are to be of such construction that the closing of which is obtained by clockwise rotation of the hand wheel, and the opening by counter-clockwise rotation.

2.6.2.5 Indicators are to be provided to show the open and closing condition of the valves, unless this can be observed in some other way; for remotely controlled valves, the remote control position is also to show the open and closing condition of the valve.

2.6.2.6 Valves and cocks are to be fitted with nameplates to indicate their purposes. The casing of non-return valves is to be permanently marked with flow direction.

2.6.2.7 The welded necks on the valve bodies are to be long enough to ensure that the valves will not deform due to welding and subsequent heat treatment of the joints.

2.6.2.8 All valves are to be subject to hydraulic tests in workshop. The hydraulic test pressure is to be 1.5 times the design pressure.

2.6.3 Air pipe closing devices

2.6.3.1 Where air pipes are required by 1.12.7.5 of PART TWO of the Rules to be fitted with automatic closing devices, they are to be designed, manufactured and tested in accordance with the requirements of Appendix 4 of this Chapter.

Section 7 TESTS

2.7.1 Hydraulic tests for piping prior to installation on board

2.7.1.1 All Classes I and II pipes and their associated fittings and, all steam pipes, feed pipes, compressed air pipes and fuel oil pipes having a design pressure greater than 0.35 MPa together with their fittings are to be hydraulically tested after completion of manufacture and before insulating and coating.

2.7.1.2 The hydraulic test pressure P_s is not to be less than that determined by the following formula:

$$P_s = 1.5p \quad \text{MPa}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter.

2.7.1.3 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300℃, test pressure P_s is to be determined by the following formula, but need not exceed 2 p.

$$P_S = 1.5\frac{[\sigma]_{100}}{[\sigma]_t}p \quad \text{MPa}$$

where: p — as defined in 2.7.1.2;

$[\sigma]_{100}$ — permissible stress for 100℃, in N/mm^2;

$[\sigma]_t$ — permissible stress for the design temperature, in N/mm^2.

The test pressure may be reduced to 1.5 *p* where it is necessary to avoid excessive stress in way of bends

and T-connections. In no case is the membrane stress to exceed 90% of the yield stress at the testing temperature.
2.7.1.4 When the hydraulic test of piping is carried out on board, it may be carried out concurrently with the tightness tests required after assembly on board.
2.7.1.5 For pipes with an internal diameter less than 15 mm, the hydraulic test may be waived.
2.7.1.6 When, for technical reasons, it is not possible to carry out complete hydraulic test for all sections piping, prior to assembly on board, applications are to be submitted to ISC for approval for testing the closing lengths of piping, particularly in respect to closing seams.

2.7.2 Hydraulic tests for valves and fittings prior to installation on board

2.7.2.1 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be hydraulically tested in accordance with recognized standards, but the test pressure is not to be less than 1.5 times the design pressure.
Valves, cocks and distance pieces intended to be fitted on the ship side below the load waterline are to be tested by hydraulic pressure not less than 0.5 MPa.

2.7.3 Testing after assembly on board

2.7.3.1 All piping systems are to be checked for leakage under working conditions.
2.7.3.2 Fuel (oil or gas) piping, heating coils in tanks, bilge pipes in way of double bottom tanks or deep tanks and hydraulic piping are to be tested by hydraulic pressure in accordance with Table 2.7.3.2.

Hydraulic tests after assembly on board **Table 2.7.3.2**

Piping system	Test pressure
Fuel (oil or gas) piping	1.5 times design pressure, but not less than 0.4 MPa
Heating coils in tanks	
Bilge pipes in way of double bottom tanks or deep tanks	Not less than test pressure of the tank
Hydraulic piping	1.25 times design pressure, but no need to exceed design pressure plus 7 MPa

2.7.3.3 Where Classes I and II pipes are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 2.7.1.1 to 2.7.1.4 after welding. During installation and before the hydraulic test is carried out, the pipe lengths may be insulated, except in way of the joints.
2.7.3.4 The hydraulic test required in 2.7.3.3 of this Section may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

Section 8 ARRANGEMENT

2.8.1 Piping arrangement

2.8.1.1 All pipes are to be properly secured, and provision is to be made to avoid excessive stresses caused by thermal expansion in pipes or due to deflection of ship structure.
2.8.1.2 Penetration pieces or steel pads are to be provided for pipes passing through watertight or gastight structures. If pipes are fixed on watertight bulkhead by bolts, bolt holes are not to pass through bulkhead. For pipes pass through deck or bulkhead with fire division, their arrangement is not to damage fire division of deck or bulkhead.
2.8.1.3 The pipe piercing the collision bulkhead below the freeboard deck (bulkhead deck for passenger ships) is to be fitted with a remotely controlled valve capable of being operated from above the freeboard deck (bulkhead deck for passenger ships). The valve is to be normally closed. If the remote control system should fail during operation of the valve, the valve is to close automatically or be capable of being closed manually from a position above the freeboard deck (bulkhead deck for passenger ships).
The above-mentioned valves are to be fitted on the forward or after side of the collision bulkhead provided that the space in which they are located is not a cargo space.
All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.
2.8.1.4 The collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank. If the forepeak is divided to hold two different kinds of liquids, the

collision bulkhead of each compartment may be allowed to be pierced below the bulkhead deck for passenger ships by one pipe.
2.8.1.5 For ships required for damage stability, the arrangement is to ensure that the continuing flooding will not extend to the compartments other than those with assumption of flooding , provided the piping system is fitted in the assumed flooding compartments.
2.8.1.6 Fresh water pipes are not to be led through oil tanks, nor oil pipes through fresh water tanks. Where it is impracticable to do so, the pipes are to be led inside an oil-tight pipe tunnel.

2.8.2 Separation of tanks
2.8.2.1 Where the following tanks are adjacent to each other, they are to be separated by cofferdams:
(1) lubricating oil tanks and fresh water tanks;
(2) boiler feed water tanks and fuel oil tanks;
(3) fresh water tanks and fuel oil tanks;
(4) boiler feed water tanks and lubricating oil tanks.
2.8.2.2 Where the fuel oil tank is directly adjacent to lubricating oil tank, the welding of the adjacent bulkhead is to be of full penetration type.

2.8.3 Corrosion protection
2.8.3.1 Steel pipes are to be protected against corrosion, and protective coatings are to be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

2.8.4 Fire protection
2.8.4.1 Air, overflow and sounding pipes for fuel oil tanks are not to be led through living quarters. Where this is not practicable, no detachable pipe joint is permissible in these spaces.
2.8.4.2 All steam, oil and water pipes as well as oil and other liquid tanks are not to be placed above or behind the switchboard. If this is not practicable, suitable protective means are to be provided.
In addition, oil pipes and oil tanks are not to be directly placed above the boilers, uptakes, steam pipes, exhaust gas pipes and silencers. If this is impracticable, effective means are to be made to prevent oil dropping onto the hot surfaces of the above-mentioned pipes or equipment.

2.8.5 Protection
2.8.5.1 Seawater pipes in cargo holds for dry cargoes, including cargo spaces of container ships, ro-ro ships, are to be protected from impact of cargo where they are liable to be damaged.
2.8.5.2 All pipes, fittings, pumps, filters and other equipment of piping systems are to be provided with drain valves or cocks where necessary.
2.8.5.3 The pipes which may be subject to a pressure greater than the design value are to be fitted with relief valves at the delivery side of pumps. The discharge from relief valves fitted in oil pipelines is to be led to the suction side of pumps or tanks. Heaters and air compressor coolers are also to be fitted with relief valves. The releasing pressure of relief valves is, in general, not to be greater than the design pressure of pipelines.
2.8.5.4 Where pressure-reducing valves are fitted in the pressure piping, a relief valve and a pressure gauge are to be fitted behind the pressure-reducing valve and a by-pass pipe fitted with a screw-down valve is to be provided. Or, at least an additional spare pressure reducing valve for replacement at any time is to be provided. The provision of pressure-reducing valves in the gas supply piping of the control system and relevant requirements are given in 2.2.2.2, PART SEVEN of the Rules.

2.8.6 Insulation
2.8.6.1 The insulation lagged on the machinery surfaces with a temperature over 220℃ is to comply with the provisions in 1.3.6.3 of this PART. The insulation in way of dismountable joints and valves is to be easily renewed.
2.8.6.2 Pipes passing through refrigerated spaces (including fish rooms), excluding those intended to serve such spaces, are to be well insulated to prevent freezing and from the steel structure.
2.8.6.3 Where the pipes pass through chambers intended for temperatures of 0℃ or below, they are in general to be insulated from the steel structure of these chambers.

2.8.7 Compensation for expansion
2.8.7.1 Suitable provision for compensation is to be made for all pipes subject to expansion, contraction or other strain, such as bends, loops, or expansion joints as required.
2.8.7.2 The adjoining pipes are to be suitably aligned and anchored. Where necessary, expansion pieces of bellows type are to be protected against mechanical damage.

2.8.7.3 In general, slip type expansion joints are only used for pipes in spaces accessible to operators for inspection during normal navigation. Slip type expansion joints are not to be used for pipes in spaces such as dry cargo tank and deep tank which are not easy to inspect. Slip type expansion joints may be used for pipes in tanks carrying the same liquid as that in the pipes.
Slip type expansion joints are not to be used in the systems listed below:
(1) class I Piping system;
(2) oil (such as fuel oil, lubricating oil, hydraulic oil, thermal oil) pipes of Class II piping system;
(3) steering gear hydraulic system;
(4) starting air and control air system;
(5) boiler feed water system;
(6) fixed gas fire extinguishing system;
(7) bilge pipelines located in cargo hold, deep tanks and double bottom tanks;
(8) cargo oil lines located in pipe duct keels;
(9) oil pipes, such as fuel oil, lubricating oil, hydraulic oil and thermal oil, of Class III systems located in machinery spaces of category A, accommodation spaces or non-mechanically ventilated pipe duct keels;
(10) pipes passing through other tanks;
(11) exhaust system.
For detailed requirements to slip type expansion joints, see relevant provisions in 2.5.3 of Section 5 and Appendix 3 of this Chapter.

2.8.8 Installation of valves and fittings

2.8.8.1 Valves, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed into but not penetrating through the pads welded on the plating. Alternatively, the studs or the bulkhead piece may be welded to the plating.
2.8.8.2 The valves and fittings fitted in engine rooms, boiler rooms, pump rooms and shaft tunnels are to be easily accessible for operation. Where the valves and fittings are situated under the floor plate not easily accessible for operation, they are to be provided with extended operating rods or tools for operation. Furthermore, holes are to be cut in the floor plate under which the valves or fittings are located and to be provided with covers.
2.8.8.3 Where relief valves are fitted in sea water systems, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.
2.8.8.4 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. Opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.
Sea valves, ship-side valves and valves on collision bulkhead are to be permanently arranged for local manual operation.

2.8.9 Installation of ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.8.9.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel sea chests attached to the shell plating. The installation of the valves or cocks is to comply with the following requirements in (1) or (2):
(1) The valves or cocks are to be secured by means of studs screwed into but not penetrating through the pads welded on the shell plating or sea chests.
(2) The valves or cocks may be secured to the distance piece welded on the shell plating or sea chests. The wall thickness of the distance piece is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the distance piece. The distance piece is to be adequately strengthened as to ensure its rigidity.
2.8.9.2 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-off valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.
2.8.9.3 Blow-off valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut.
2.8.9.4 It is to be avoided to locate the overboard discharges in way of the areas where the lifeboats and accommodation ladders are lowered. Where this is not practicable, suitable means are to be provided to

prevent any discharge of water into the lifeboats or onto the accommodation ladders.

2.8.9.5 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. The operating position of hand wheel or manual operating device of main sea inlet valve is to be situated not less than 450 mm above the lower platform.

If an inlet or outlet pipeline passes through wing tank, the above-mentioned ship-side valve may be installed on inner bulkhead of wing tank. The wall thickness of pipes between inner bulkhead and shell plate of wing tank is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the pipes.

2.8.9.6 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and sea chests. The direction of grating bars is to be in line with the length of the ship. The net area through the gratings is not to be less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air.

2.8.9.7 Ship-side valves and fittings as well as sea chests, if made of steel, are to be suitably protected against wastage.

2.8.9.8 Sea chests are to be so arranged as to avoid the formation of air pocket. Where a vent pipe is fitted on the top of the sea chest, a screw-down valve is to be fitted at the root of the vent pipe. The open end of the vent pipe is to be extended to a position above the bulkhead deck or to be led overboard in the vicinity of the bulkhead deck and a ship-side screw-down valve is to be fitted.

2.8.9.9 For sea connections for ships having ice notations, see relevant provisions specified in Chapter 14 of this PART.

Appendix 1 PRODUCTION AND APPLICATION OF PLASTIC PIPING SYSTEMS ON SHIPS①

1.1 Terms and Definitions of this Appendix

1.1.1 "Plastic(s)" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fiber reinforced plastics − FRP. Plastic(s) includes synthetic rubber and materials of similar thermos/mechanical properties.

1.1.2 "Pipes/piping systems" means those made of plastics and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria.

1.1.3 "Joint" means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints listed in Table 2.5.3.1(1), Chapter 2 of this PART.

1.1.4 "Fittings" means bends, elbows, fabricated branch pieces etc. of plastic materials.

1.1.5 "Nominal pressure" means the maximum permissible working pressure which should be determined in accordance with the requirements in 1.3.1 of this Appendix.

1.1.6 "Design pressure" means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.1.7 "Fire endurance" means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

1.1.8 "Essential to the safety of ship" means all piping systems that in event of failure will pose a threat to personnel and the ship (piping systems essential to the safety are provided by Table 1.4.1).

1.1.9 "Essential services" are those services essential for propulsion and steering and safety of the ship as specified in 1.1.2, Chapter 1, PART FOUR of the Rules.

1.2 Scope

1.2.1 This Appendix is applicable to piping systems on ships, including pipe joints and fittings, made predominately of other material than metal.

1.2.2 The use of mechanical joints approved for the use in metallic piping systems only are not applicable in this Appendix.

1.2.3 Piping systems intended for non-essential services are to meet only the requirements of recognized standards and 1.3.1(3)②, 1.4.2, 1.5.2~1.5.7 and 1.6 of this Appendix.

1.3 General Requirements

The specification of piping is to be in accordance with a recognized national or international standard acceptable to ISC. In addition, the following requirements apply:

1.3.1 Strength

(1) The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 0.1 MPa, relative humidity 30%, environmental and carried fluid temperature 298 K (25℃).

(2) The strength of fittings and joints is not to be less than that of the pipes.

(3) The nominal pressure is to be determined from the following conditions:

① Internal Pressure

For an internal pressure, the following is to be taken whichever is smaller:

$$Pn \text{ int } \frac{c}{\lambda} Psth/4 \quad \text{or} \quad Pn \text{ int } \frac{c}{\lambda} Plth/2.5 \text{ where:}$$

Psth — short-term hydrostatic test pipe failure pressure, in MPa;

Plth — long-term hydrostatic test pipe failure pressure (> 100,000 h), in MPa.

② External Pressure(for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS II-1/8-1, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

For an external pressure:

---

① It is addressed by IACS according to the provisions of IMO resolution A.753(18), as amended by IMO Res. MSC.313(88) and IMO Res. MSC. 399(95).

$$Pn\ ext \leq Pcol/3$$

where: Pcol — pipe collapse pressure, in MPa.

In no case is the pipe collapse pressure to be less than 0.3 MPa.

The maximum working external pressure is a sum of the vacuum inside the pipe and a head of liquid acting on the outside of the pipe.

(4) Notwithstanding the requirements of (3)① or (3)② above as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of (3)② above are to be met.

(5) The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with manufacturer's recommendations.

1.3.2 Axial Strength

(1) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

(2) In the case of fiber reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see 1.3.1 of this Appendix).

1.3.3 Impact Resistance

(1) Plastic pipes and joints are to have a minimum resistance to impact in accordance with recognized national or international standards.

(2) After testing, the specimen is to be tested to a hydraulic pressure equal to 2.5 times the design pressure for at least 1 h.

1.3.4 Temperature

(1) The permissible working temperature depending on the working pressure is to be in accordance with manufacturer's recommendations, but in each case it is to be at least 20℃ lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2 method A, or equivalent, e.g. ASTMD648-18.

(2) The minimum heat distortion/deflection temperature is not to be less than 80℃.

1.4 Requirements for Pipes/Piping Systems Depending on Service and/or Locations

1.4.1 Fire Endurance

(1) Pipes and their associated joints and fittings whose integrity is essential to the safety of ships, including plastic piping required by SOLAS II-2/21.4 to remain operational after a fire casualty, are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO resolution A.753 (18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(2) Unless instructed otherwise by the Administration, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings[①]:

① Pipes:

- for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness[②]
- for sizes with outer diameter ≥ 200 mm one test specimen for each category of t/d (D = outer diameter, t = structural wall thickness). A scattering of ±10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

② Joints

- Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen.

(3) Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1 or 2 of the IMO Res.A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95). During the test it is not permitted to replace media drained by fresh water or nitrogen.

(4) Depending on the capability of a piping system to maintain its strength and integrity, there exist five different levels of fire endurance for piping systems.

① Level 1: Piping having passed the fire endurance test specified in Appendix 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for duration of

---

① A test specimen incorporating several components of a piping system may be tested in a single test.

② Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested. If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1).

② Level 1W: Piping systems similar to level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable[①], which is considered to meet level 1W fire endurance standard (L1W).

③ Level 2: Piping having passed the fire endurance test specified in Appendix 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of 30 min in the dry condition is considered to meet level 2 fire endurance standard (L2).

④ Level 2W: Piping systems similar to level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable[①], which is considered to meet level 2W fire endurance standard (L2W).

⑤ Level 3: Piping having passed the fire endurance test specified in Appendix 2 of IMO resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of 30 min in the wet condition is considered to meet level 3 fire endurance standard (L3).

(5) Permitted use of piping depending on fire endurance, location and piping system is given in Table 1.4.1.

(6) For Safe Return to Port purposes (SOLAS II-2/21.4), plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

1.4.2 Flame Spread

(1) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels and ducts, if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead, are to have low surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(2) Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as listed in Appendix 3 of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(3) Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635, or in other national equivalent standards. Under the procedure of ASTM D635 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

1.4.3 Fire Protection Coatings

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

① The pipes are generally to be delivered from the manufacturer with the protective coating on.

② The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.

③ In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations, and elasticity are to be taken into account.

④ The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

1.4.4 Electrical Conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed 1×10^5 Ω/m.

---

① The flow loss must be taken into account when dimensioning the system.

Fire-resistance Requirements *Table 1.4.1*

N piping system		Parts										
		A	B	C	D	E	F	G	H	I	J	K
		Machinery space of category A	Other machinery space and pump tank	Cargo pump room	Ro-ro cargo hold	Other cargo hold	Cargo oil tank	Fuel oil tank	Ballast tank	Cofferdam, void, tunnel and duct	Accommodation and service spaces, control room	Open deck
1	2	3	4	5	6	7	8	9	10	11	12	13
Cargo oil (flammable cargo, with flash point ≤60℃)												
1 cargo oil pipeline		NA	NA	L1	NA	NA	O	NA	O⑩	O	NA	L1②
2 crude oil pipeline		NA	NA	L1	NA	NA	O	NA	O⑩	O	NA	L1②
3 gas venting pipeline		NA	NA	NA	NA	NA	O	NA	O⑩	O	NA	×
Inert gas												
4 water-sealed discharge pipeline		NA	NA	O①	NA	NA	O①	O①	O①	O①	NA	O
5 detergent discharge pipe		O①	O①	NA	NA	NA	NA	NA	O①	O①	NA	O
6 main pipe		O	O	L1	NA	NA	NA	NA	NA	O	NA	L1⑥
7 distribution pipe		NA	NA	L1	NA	NA	O	NA	NA	O	NA	L1②
Flammable liquid (flash point > 60℃)												
8 cargo oil pipe		×	×	L1	×	×	NA③	O	O⑩	O	NA	L1
9 fuel oil pipe		×	×	L1	×	×	NA③	O	O	O	L1	L1
10 lubricating oil pipe		×	×	L1	×	×	NA	NA	NA	O	L1	L1
11 hydraulic oil pipe		×	×	L1	×	×	O	O	O	O	L1	L1
Sea water①												
12 bilge main and branch pipes		L1⑦	L1⑦	L1	×	×	NA	O	O	O	NA	L1
13 fire main pipe and water spry pipe		L1	L1	L1	×	NA	NA	NA	O	O	×	L1
14 foam system		L1W	L1W	L1W	NA	NA	NA	NA	NA	O	L1W	L1W
15 automatic jet system		L1W	L1W	L3	×	NA	NA	NA	O	O	L3	L3
16 ballast system		L3	L3	L3	L3	×	O⑩	O	O	O	L2W	L2W
17 essential services of cooling water		L3	L3	NA	NA	NA	NA	NA	O	O	NA	L2W
18 fixed machinery system for cleaning tank		NA	NA	L3	NA	NA	O	NA	O	O	NA	L3②
19 non-essential system		O	O	O	O	O	NA	O	O	O	O	O
Fresh water												
20 essential services of cooling water		L3	L3	NA	NA	NA	NA	O	O	O	L3	L3
21 condensate back water		L3	L3	L3	O	O	NA	NA	NA	O	O	O
22 non-essential system		O	O	O	O	O	NA	O	O	O	O	O
Sanitary/drainage/discharge												
23 deck drainage (inside)		L1W④	L1W④	NA	L1W④	O	NA	O	O	O	O	O
24 sanitary drainage (inside)		O	O	NA	O	O	NA	O	O	O	O	O
25 scupper and discharge (overboard)		O①⑧	O①⑧	O①⑧	L①⑧	O①⑧	O	O	O	O	O①⑧	O
Sounding/air												
26 water tank / dry space		O	O	O	O	O	O⑩	O	O	O	O	O
27 oil tank (flash point > 60℃)		×	×	×	×	×	×③	O	O⑩	O	×	×
Miscellaneous												
28 air pipe for control		L1⑤	L1⑤	L1⑤	L1⑤	L1⑤	NA	O	O	O	L1⑤	L1⑤
29 service air pipe (non-essential service)		O	O	O	O	O	NA	O	O	O	O	O
30 salt water pipe		O	O	NA	O	O	NA	NA	NA	O	O	O
31 auxiliary low pressure steam pipe (≤ 0.7 MPa)		L2W	L2W	O⑨	O⑨	O⑨	O	O	O	O	O⑨	O⑨
32 central vacuum		NA	NA	NA	O	NA	NA	NA	NA	O	O	O
33 exhaust Gas Cleaning		L3①	L3①	NA	NA	NA	NA	NA	NA	O	L3①，⑪	O

N piping system	Parts										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery space of category A	Other machinery space and pump tank	Cargo pump room	Ro-ro cargo hold	Other cargo hold	Cargo oil tank	Fuel oil tank	Ballast tank	Cofferdam, void, tunnel and duct	Accommodation and service spaces, control room	Open deck
System Effluent Line										NA	
34 urea Transfer/Supply System (SCR installations)	L1 ⑫	L1 ⑫	NA	NA	NA	NA	NA	NA	O	L3○11 NA	O

Notes:

L1—Fire endurance test (Annex 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 60 min;

L2—Fire endurance test (Annex 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 30 min;

L3—Fire endurance test (Annex 2 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in wet conditions, 30 min;

L1W—Fire endurance test (see 1.4.1(2) of this Appendix);

L2W—Fire endurance test(see 1.4.1(2) of this Appendix);

O — No fire endurance test required;

NA—Not applicable;

× — Metallic materials having a melting point greater than 925℃.

① Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).

② Remote closing valves to be provided at the cargo tanks.

③ When cargo tanks contain flammable liquids with f.p. > 60 ℃, "O" may replace "NA" or "×".

④ For drains serving only the space concerned, "O" may replace "L1W".

⑤ When controlling functions are not required in statutory requirements or guidelines, "O" may replace "L1".

⑥ For pipe between machinery space and deck water seal, "O" may replace "L1".

⑦ For passenger vessels, "×" is to replace "L1".

⑧ Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the Protocol of 1988 relating to the International Convention on Load Lines, 1966, should be "×" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent down-flooding.

⑨ For essential services, such as fuel oil tank heating and ship's whistle, "×" is to replace "O".

⑩ For tankers where compliance with paragraph 3.6, regulation 19 of Annex I of MARPOL is required, "NA" is to replace "O".

⑪ L3 in service spaces, NA in accommodation and control spaces.

⑫ Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.

⑬ For Passenger Ships subject to SOLAS II-2, Reg.21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with MSC Circular MSC.1/Circ.1369, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

Location Definition:

A —Machinery spaces of category A: Machinery spaces of category A as defined in SOLAS① II-2/3.31.

B—Other machinery spaces: Spaces, other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.

C—Cargo pump rooms: Spaces containing cargo pumps and entrances and trunks to such spaces.

D—Ro-ro cargo holds: Ro-ro cargo holds are ro-ro cargo spaces and special category spaces as defined in SOLAS① regulation II-2/3.41 and 3.46.

E—Other dry cargo holds: All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.

F—Cargo tanks: All spaces used for liquid cargo and trunks to such spaces.

G—Fuel oil tanks: All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.

H—Ballast water tanks: All spaces used for ballast water and trunks to such spaces.

I— Cofferdams, voids, etc.: Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.

J—Accommodation and service spaces: Accommodation spaces, service spaces and control stations as defined in SOLAS①

① SOLAS Chapter II-2.

regulation II-2/3.1, 3.45, 3.18.
K—Open decks: Open deck spaces as defined in SOLAS① regulation II-2/9.2.2.3.2(5).

1.5 *Material Approval and Quality Control During Manufacture*

1.5.1 Except as required in 1.2.3 of this Appendix, Prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with this Appendix.

1.5.2 For prototype testing, representative samples of pipes and fittings are to be selected to the satisfaction of ISC.

1.5.3 The manufacturer is to have quality system that meets ISO 9000 series standards or equivalent.

The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

1.5.4 Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1.5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay-up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognized national or international standard accepted by ISC to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

1.5.5 Pipes and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

1.5.6 In case the manufacturer does not have an approved quality system complying with ISO 9000 series or equivalent, pipes and fittings are to be tested in accordance with this Appendix to the satisfaction of the Surveyors for every batch of pipes.

1.5.7 Depending upon the intended application, ISC may require the pressure testing of each pipe and/or fitting.

1.6 *Installation*

1.6.1 Supports

(1) Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, pipe length, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected. Combination of loads is to be considered.

(2) Each support is to evenly distribute the load of the pipe and its contents over the full width of the support. Measures are to be taken to minimize wear of the pipes where they contact the supports.

(3) Heavy components in the piping system such as valves and expansion joints are to be independently supported.

1.6.2 Expansion

(1) Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

① the difference in the coefficients of thermal expansion;

② deformations of the ship's hull and its structure.

(2) When calculating the thermal expansions, account is to be taken of the system working temperature and the temperature at which assembly is performed.

1.6.3 External Loads

(1) When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowances are to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

(2) Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with 1.3.1 of this Appendix, may be increased taking into account the conditions encountered during service on board ships.

(3) Pipes are to be protected from mechanical damage where necessary.

1.6.4 Strength of Connections

(1) The strength of connections is not to be less than that of the piping system in which they are installed.

(2) Pipes may be assembled using adhesive-bonded, welded, flanged or other joints.

(3) Adhesives, when used for joint assembly, are to be suitable for providing a permanent seal between the

pipes and fittings throughout the temperature and pressure range of the intended application.
(4) Tightening of joints is to be performed in accordance with manufacturer's instructions.

1.6.5 Installation of Conductive Pipes

(1) In piping systems for fluids with conductivity less than 1,000 pS/m, such as refined products and distillates use is to be made of conductive pipes.
(2) Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1×10^6 Ω/m. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.
(3) After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection.

1.6.6 Application of Fire Protection Coatings

(1) Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance as for 1.4.3 of this Appendix, after performing hydrostatic pressure tests of the piping system.
(2) The fire protection coatings are to be applied in accordance with manufacturer's recommendations, using a procedure approved in each particular case.

1.6.7 Penetration of Divisions

(1) Where plastic pipes pass through A or B class divisions, arrangements are to be made to ensure that the fire endurance is not impaired. These arrangements are to be tested in accordance with Recommendations for fire test procedures for A, B and F bulkheads 2010 FTP Code, annex 1, part 3 (Res. MSC.307(88) as amended by Res.MSC.437(99)).
(2) When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in 1.3.1(3)② of this Appendix, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.
(3) If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

1.6.8 Control during Installation

(1) Installation is to be in accordance with the manufacturer's guidelines.
(2) Prior to commencing the work, joining techniques are to be approved.
(3) The tests and examinations specified in this Appendix are to be completed before shipboard piping installation commences.
(4) The personnel performing this work are to be properly qualified and certified to the satisfaction of ISC.
(5) The procedure of making bonds is to include:

① materials used;
② tools and fixtures;
③ joint preparation requirements;
④ cure temperature;
⑤ dimensional requirements and tolerances;
⑥ tests acceptance criteria upon completion of the assembly.

(6) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be re-qualified.

1.6.9 Bonding Procedure Quality Testing

(1) A test assembly is to be fabricated in accordance with the procedure to be qualified and it is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.
(2) When the test assembly has been cured, it is to be tested to a hydraulic pressure equal to 2.5 times the design pressure for at least 1 h. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.
(3) Selection of the pipes used for test assembly, is to be in accordance with the following:

① When the largest size to be joined is 200 mm nominal outside diameter, or smaller, the test assembly is to be the largest piping size to be joined.
② When the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is greater.

(4) When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

1.6.10 Testing after Installation on Board

(1) Piping systems for essential services are to be tested to a pressure equal to 1.5 times the design pressure or 0.4 MPa, whichever is greater. Notwithstanding the requirement above, the requirement in 1.6.10(2) may be applied to open ended pipes (drains, effluent, etc.).
(2) Piping systems for non-essential services are to be checked for leakage under operational conditions.
(3) For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

1.7 *Test specification for plastic pipes*

1.7.1 General requirements

1.7 contains requirements for the type approval of plastic pipes. It is applicable to piping systems, including pipe joints and fittings, made predominately of other material than metal.

1.7.2 Documentation

The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

(1) General information:

① Pipe and fitting dimensions;
② Maximum internal and external working pressure;
③ Working temperature range;
④ Intended services and installation locations;
⑤ The level of fire endurance;
⑥ Electrically conductive;
⑦ Intended fluids;
⑧ Limits on flow rates;
⑨ Serviceable life;
⑩ Installation instructions;
⑪ Details of marking.

(2) Drawings and supporting documentation:

① Certificates and reports for relevant tests previously carried out;
② Details of relevant standards;
③ All relevant design drawings, catalogues, data sheets, calculations and functional descriptions;
④ Fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

(3) Materials(as applicable):

① The resin type;
② Catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed;
③ A statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed;
④ Full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate;
⑤ Cure / post-cure conditions. The cure and post-cure temperatures and times employ resin / reinforcement ratio;
⑥ Winding angle and orientation.
⑦ Joint bonding procedures and qualification tests results, see 1.6.8(5) of this Appendix.

1.7.3 Testing

Testing is to demonstrate compliance of the pipes, fittings and joints for which type approval is sought with the requirement of this Appendix.

Pipes, joints and fittings are to be tested for compliance with the requirements of standards① acceptable to ISC.

① For the list of standards refer to IACS Recommendation No.86.

Appendix 2 FLEXIBLE HOSES

1.1 *Definition*

1.1.1 Flexible hose assembly① means short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

Note: Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1.5 m in length.

1.2 *Scope*

1.2.1 This Appendix applies to flexible hoses of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. This Appendix may also be applied to temporary connected flexible hoses or hoses of portable equipment.

1.2.2 Flexible hose assemblies satisfying the requirements of this Appendix may be accepted for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems and Class III steam systems. Flexible hoses in high pressure fuel oil injection systems are not to be accepted.

1.2.3 This Appendix is not applicable to hoses intended to be used in fixed fire extinguishing systems.

1.3 *Design and construction*

1.3.1 Flexible hoses constructed of rubber materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single, double or more, closely woven integral wire braid or other suitable material reinforcement.

Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable.

Where rubber or plastics materials hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the reinforcement mentioned above. Flexible hoses for use in steam systems are to be of metallic construction.

1.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with the requirements of 2.5.3 of this Chapter as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

1.3.3 The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding.

In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0.5 MPa and provided there are double clamps at each end connection.

1.3.4 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 1.5 of this Appendix are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

1.3.5 The following flexible hose assemblies constructed of non-metallic materials are to be of fire-resistant type②, except in cases where such hoses are installed on open decks, as defined in SOLAS regulation II-2/9.2.3.3.2.2(10) as amended by IMO resolutions up to MSC.421(98) and not used for fuel oil lines:

(1) used for flammable media;

(2) used for sea water systems where failure may result in flooding.

1.3.6 Flexible hose assemblies are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions.

1.4 *Installation*

1.4.1 In general, flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

---

① Flexible hoses are to be designed and manufactured according to the recognized national or international standards.

② Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

1.4.2 Flexible hose assemblies are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.
1.4.3 The number of flexible hoses, in piping systems mentioned in 1.2.2 is to be kept to minimum and to be limited for the purpose stated in 1.2.1.
1.4.4 Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection.
1.4.5 Flexible hoses are to be installed in clearly visible and readily accessible locations.
1.4.6 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(1) orientation;
(2) end connection support (where necessary);
(3) avoidance of hose contact that could cause rubbing and abrasion;
(4) minimum bend radii.

1.5 *Tests*

1.5.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programs for flexible hose assemblies are to be submitted for approval and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.
1.5.2 The tests are, as applicable, to be carried out on different nominal diameters of hose type complete with end fittings for pressure, burst, impulse resistance and fire resistance in accordance with the requirements of the relevant standard①.
Note:
Prototype tests are to be carried out for each size of hose assembly. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:
(1) the smallest diameter,
(2) the largest diameter,
(3) Intermediate diameters selected based on the principle that prototype tests carried out
for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0.5 D and 2 D.
For fire resistance tests the specimens shall be selected in accordance with ISO 15540.
1.5.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard② to demonstrate they are able to withstand a pressure not less than four times its design pressure without indication of failure or leakage.

1.6 *Marking*

1.6.1 Flexible hoses are to be permanently marked with the following details:
(1) hose manufacturer's name or trademark;
(2) date of manufacture (month / year);
(3) designation type reference;
(4) nominal diameter;
(5) pressure rating;
(6) temperature rating.
Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

---

① The following standards are to be used as applicable:
(1) ISO 6802 – Rubber and plastics hoses and hose assemblies with wire reinforcements – Hydraulic impulse test with flexing;
(2) ISO 6803 – Rubber or plastics hoses and hose assemblies with wire reinforcements 15 test without flexing;
(3) ISO 15540 – Ships and marine technology – Fire resistance of hose assemblies – Test methods;
(4) ISO 15541 – Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench;
(5) ISO 10380 – Pipework – Corrugated metal hoses and hose assemblies.

② The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 × MWP.

Appendix 3 TYPE APPROVAL OF MECHANICAL JOINTS

1.1 *General*

1.1.1 This Appendix describes the type testing condition for type approval of mechanical joints intended for use in marine piping systems. Conditions outlined in these requirements are to be fulfilled before Type Approval Certificates are issued.

Alternative testing in accordance with national or international standards may also be accepted.

1.2 *Scope*

1.2.1 This Appendix is applicable to mechanical joints defined in 2.5.3 of this Chapter, including compression couplings and slip-on joints of different types for marine use.

1.3 *Documentation*

1.3.1 Following documents and information are to be submitted by manufacturer for assessment and/or approval:

(1) product quality assurance system implemented;

(2) complete description of the product;

(3) typical sectional drawings with all dimensions necessary for evaluation of joint design;

(4) complete specification of materials used for all components of the assembly;

(5) proposed test procedure as required in 1.5 of this Appendix and corresponding test reports or other previous relevant tests;

(6) initial information:

① maximum design pressures (pressure and vacuum);

② maximum and minimum design temperatures;

③ conveyed media;

④ intended services;

⑤ maximum axial, lateral and angular deviation, allowed by manufacturer;

⑥ installation details.

1.4 *Materials*

1.4.1 The materials used for mechanical joints are to comply with the requirements of 2.5.3.3 of this Chapter.

1.4.2 The manufacturer has to submit evidence to substantiate that all components are adequately resistant to working the media at design pressure and temperature specified.

1.5 *Testing, procedures and requirements*

The aim of tests is to demonstrate ability of the pipe joints to operate satisfactory under intended service conditions. The scope and type of tests to be conducted (e.g. applicable tests), sequence of testing, and the number of specimen, is subject to approval and will depend on joint design and its intended service in accordance with the requirements of this Appendix.

Unless otherwise specified, the water or oil as test fluid is to be used.

1.5.1 Test program

Testing requirements for mechanical joints are to be as indicated in Table 1.5.1.

1.5.2 Selection of test specimen

Test specimens are to be selected from production line or at random from stock.

Where there is a variety of size of joints requiring approval, a minimum of three separate sizes, representative of the range, from each type of joint to be tested in accordance with Table 1.5.1 are to be selected.

1.5.3 Mechanical Joint Assembly

Assembly of mechanical joints should consist of components selected in accordance with 1.5.2 and the pipe sizes appropriate to the design of the joints.

Where pipe material would affect the performance of mechanical joints, the selection of joints for testing is to take the pipe material into consideration.

Where not specified, the length of pipes to be connected by means of the joint to be tested is to be at least five times the pipe diameter. Before assembling the joint, conformity of components to the design requirements, is to be verified. In all cases the assembly of the joint is to be carried out only according to he manufacturer's instructions. No adjustment operations on the joint assembly, other than that specified by

the manufacturer, are permitted during the test.

Test Procedures of Mechanical Joints *Table 1.5.1*

Tests		Types of Mechanical Joints			Notes and references
		Compression couplings and pipes unions	Slip-on joints		
			Grip type & slip type machined grooved type	Slip type	
1	Tightness test	×	×	×	1.5.5(1)
2	Vibration (fatigue) test	×	×	–	1.5.5(2)
3	Pressure pulsation test①	×	×	–	1.5.5(3)
4	Burst pressure test	×	×	×	1.5.5(4)
5	Pull-out test	×	×	–	1.5.5(5)
6	Fire endurance test	×	×	×	1.5.5(6), if required by 2.5.3.7 of this Chapter
7	Vacuum test	×③	×	×	1.5.5(7), for suction lines only
8	Repeated assembly test	×②	×	–	1.5.5(8)

Abbreviations: × test is required
– test is not required

Notes:

① For use in those systems where pressure pulsation other than water hammer is expected.

② Except press type and swage type.

③ Except joints with metal-to-metal tightening surface.

1.5.4 Test results acceptance criteria

Where a mechanical joint assembly does not pass all or any part of the tests in Table 1.5.1, two assemblies of the same size and type that failed are to be tested and only those tests which mechanical joint assembly failed in the first instance, are to be repeated. In the event where one of the assemblies fails the second test, that size and type of assembly is to be considered unacceptable.

The methods and results of each test are to be recorded and reproduced as and when required.

1.5.5 Methods of tests

(1) Tightness test

In order to ensure correct assembly and tightness of the joints, all mechanical joints are to be subject to a tightness test, as follows:

① Mechanical joint assembly test specimen is to be connected to the pipe or tubing in accordance with the requirements of 1.5.3 and the manufacturer's instructions, filled with test fluid and de-aerated.
Mechanical joints assemblies intended for use in rigid connections of pipe lengths, are not to be longitudinally restrained.
Pressure inside the joint assembly is to be slowly increased to 1.5 times of design pressure. This test pressure is to be retained for a minimum period of 5 min.
In the event where there is a drop in pressure or there is visual indication of leakage, the test (including fire test) is to be repeated for two test pieces. Where one test piece fails in the repeat test, the coupling will be regarded as having failed.
Other alternative tightness test procedure, such as pneumatic test, may be accepted.

② For compression couplings, a static gas pressure test is to be carried out to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 7.0 MPa, whichever is less.

③ Where the tightness test is carried out using gaseous media as permitted in ① above, then the static pressure test mentioned in ② above need not be carried out.

(2) Vibration (fatigue) test

In order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions, mechanical joints assembly is to be subject to the following vibration test.

Conclusions of the vibration tests should show no leakage or damage.

① Testing of compression couplings and pipe unions
Compression couplings and pipe unions intended for use in rigid pipe connections are to be tested in accordance with this method described as follows.
Rigid connections are joints, connecting pipe length without free angular or axial movement.
Two lengths of pipe is to be connected by means of the joint to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibration rig. The test rig and the joint assembly specimen being tested is to be arranged as shown in Figure 1.

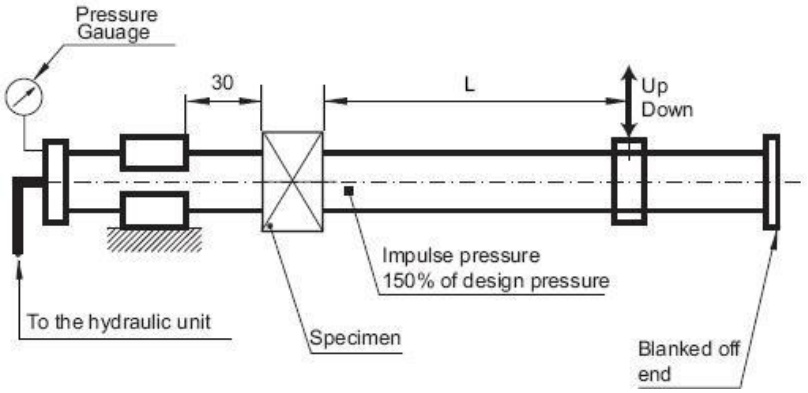


Figure 1

The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint.
Pressure during the test is to be monitored. In the event of drop in the pressure and visible leakage, the test is to be repeated as described in 1.5.4 of this Appendix.
Visual examination of the joint assembly is to be carried out.
Re-tightening may be accepted once during the first 1,000 cycles.
Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = \frac{2SL^2}{3ED}$$

where: A – single amplitude, in mm;
L – length of the pipe, in mm;
S – allowable bending stress in N/mm^2 based on 0.25 of the yield stress;
E – modulus of elasticity of tube material (for mild steel, E = 210 kN/mm^2);
D – outside diameter of tube, in mm.

Test specimen is to withstand not less than 10^7 cycles with frequency 20 to 50 Hz without leakage or damage.

② Grip type and machine grooved type joints

Grip type joints and other similar joints containing elastic elements are to be tested in accordance with the following method.
A test rig of cantilever type used for testing fatigue strength of components may be used. The test specimen being tested is to be arranged in the test rig as shown in Figure 2.

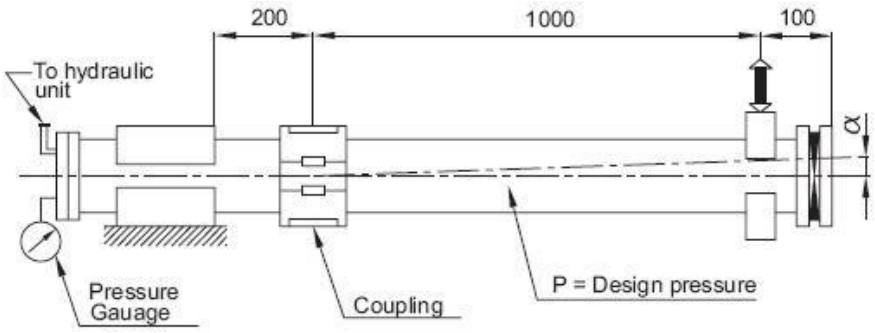


Figure 2

Two lengths of pipes are to be connected by means of joint assembly specimen to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibrating element on the rig. The length of pipe connected to the fixed end should be kept as short as possible and in no case exceeds 200 mm.
Mechanical joint assemblies are not to be longitudinally restrained.
The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the

joint. Preliminary angle of deflection of pipe axis is to be equal to the maximum angle of deflection, recommended by the manufacturer. The amplitude is to be measured at 1 m distance from the center line of the joint assembly at free pipe end connected to the rotating element of the rig (see Figure 2). Parameters of testing are to be as indicated in the table below and to be carried out on the same assembly:

Number of cycles	Amplitude, in mm	Frequency, in Hz
3×10^6	± 0.06	100
3×10^6	± 0.5	45
3×10^6	± 1.5	10

Pressure during the test is to be monitored. In the event of a drop in the pressure or visible leakage, the test is to be repeated as described in 1.5.4 of this Appendix.

Visual examination of the joint assembly is to be carried out.

(3) Pressure pulsation test

In order to determine capability of mechanical joint assembly to withstand pressure pulsation likely to occur during working conditions, joint assemblies intended for use in rigid connections of pipe lengths, are to be tested in accordance with the following method.

The mechanical joint test specimen for carrying out this test may be the same as that used in the test in 1.5.5(1) provided it passed that test.

The vibration test in 1.5.5(2) and the pressure pulsation test are to be carried out simultaneously for compression couplings and pipe unions.

The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in Figure 3.

Impulse pressure is to be raised from 0 to 1.5 times the design pressure of the joint with a frequency equal to 30 to 100 cycles per minute. The number of cycles is not to be less than 5×10^5.

The mechanical joint is to be examined visually for sign of leakage or damage during the test.

(4) Burst pressure test

In order to determine the capability of the mechanical joint assembly to withstand a pressure as stated by 2.5.3.8 of this Chapter, the following burst test is to be carried out.

Mechanical joint test specimen is to be connected to the pipe or tubing in accordance with the requirements of 1.5.3, filled with test fluid, de-aerated and pressurized to test pressure with an increasing rate of 10% per minute or test pressure. The mechanical joint assembly intended for use in rigid connections of pipe lengths is not to be longitudinally restrained.

Duration of this test is not to be less than 5 min at the maximum pressure. This pressure value is to be in compliance with the requirements of 2.5.3.8 of this Chapter.

Where considered convenient, the mechanical joint test specimen used in tightness test in 1.5.5(1) may be used for the burst test provided it passed the tightness test.

The specimen may have small deformation whilst under test pressure, but no leakage or visible cracks are permitted.

(5) Pull-out test

In order to determine ability of a mechanical joint assembly to withstand axial load likely to be encountered in service without the connecting pipe from becoming detached, following pull-out test is to be carried out.

Pipes of suitable length are to be fitted to each end of the mechanical joints assembly test specimen. The test specimen is to be pressurized to design pressure. When pressure is attained, an external axial load is to be imposed with a value calculated by the following formula:

$$L = \frac{\pi}{4} D^2 p$$

where: D – pipe outside diameter, in mm;

p – design pressure, in N/mm^2;

L – applied axial load, in N.

The pressure and axial load are to be maintained for a period of 5 min.

During the test, pressure is to be monitored and relative movement between the joint assembly and the pipe is to be measured.

The mechanical joint assembly is to be visually examined for drop in pressure and signs of leakage or damage.

There are to be no movement between mechanical joint assembly and the connecting pipes.

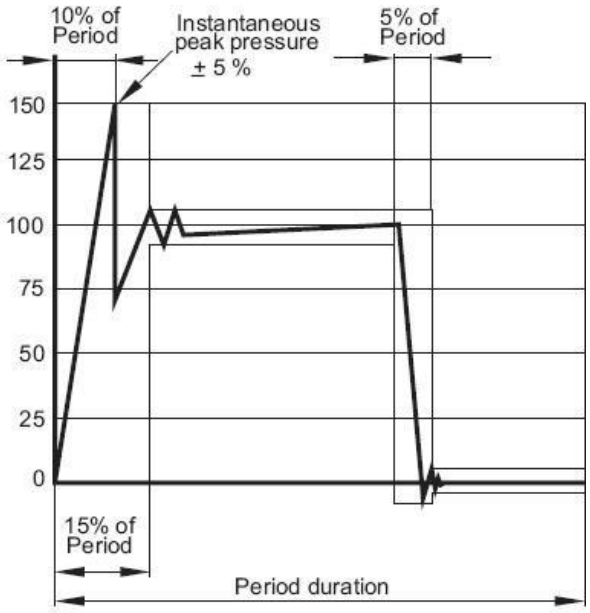


Figure 3 Impulse pressure diagram

(6) Fire endurance test

In order to establish capability of the mechanical joints to withstand effects of fire which may be encountered in service, mechanical joints are to be subjected to a fire endurance test. The fire endurance test is to be conducted on the selected test specimens as per the following standards.

① ISO 19921: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.

② ISO 19922: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

Clarifications to the standard requirements in ISO19921, Paragraphs 7.2, 7.4, 7.6 and 7.7:

① If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint (however of at least 5 bar), the subsequent pressure test is to be carried out to 1.5 times the design pressure.

② If the fire test is required in Table 2.5.3.1(2) to be "8 min dry + 22 min wet" or "30 min dry", i.e. conducted for a period of time without circulating of water, the following test conditions apply:

Test condition "8 min dry + 22 min wet"

The test piece is not required to be rinsed with the test medium (water) in preparation for the test as required in Paragraph 7.2 of ISO 19921. The exposure to fire is to be started and continued for 8 minutes with the sample dry; after 8 minutes of dry test condition the piping system is to be filled with water and test pressure is to be increased up to at least 5 bar within 2 minutes, then maintained to at least 5 bar. After further 22 minutes (i.e. 30 minutes from initial exposure to fire) the exposure to fire is to be stopped and a hydrostatic pressure test as specified in ① is to be carried out.

Test condition "30 min dry"

The exposure to fire is to be started and continued for 30 minutes with the sample dry. After 30 minutes the exposure to fire is to be stopped and a hydrostatic pressure test as specified in ① is to be carried out.

Note:

For fire tests in dry condition the pressure inside the test specimen is to be monitored for a rise due to heating of the enclosed air. Means of pressure relief should be provided where deemed necessary.

High pressures created during this test can result in failure of the test specimen. Precautions shall be taken to protect personnel and facilities.

Paragraph 7.5 of ISO 19921 does not apply to the dry tests and no forced air circulation is to be arranged.

For fire endurance test requiring exposure time greater than 30 minutes test conditions are adjusted to meet the extended required total exposure time. In all cases for dry-wet test the minimum dry test exposure time is 8 minutes.

③ A selection of representative nominal bores may be tested in order to evaluate the fire resistance of a series or range of mechanical joints of the same design. When a mechanical joint of a given nominal bore (D_n) is so tested then other mechanical joints falling in the range D_n to $2 \times D_n$ (both inclusive) are considered accepted.

④ Alternative test methods and/or test procedures considered to be at least equivalent may be accepted in cases where the test pieces are too large for the test bench and cannot be completely enclosed by the flames.

⑤ Where thermal insulation is acceptable as a means of providing fire resistance, following requirements apply:

a. Thermal insulation materials applied on couplings are to be non-combustible according to ISO 1182 as required by the Fire Test Procedures Code defined in Regulation 3 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98).
Precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b. At least the fire endurance and the vibration testing in Table 1.5.1 are to be carried out with thermal insulation in place.

c. A service restriction is to be stated on the type approval certificate that the mechanical joints are to be fitted with thermal insulation during the installation in cases where the mechanical joints are used where fire resistance is required, unless mechanical joints are delivered already fitted with thermal insulation before installation.

(7) Vacuum test

In order to establish capability of mechanical joint assembly to withstand internal pressures below atmosphere, similar to the conditions likely to be encountered under service conditions, following vacuum test is to be carried out.

Mechanical joint assembly is to be connected to a vacuum pump and subjected to a pressure 0.0170 MPa absolute. Once this pressure is stabilized, the test specimens under test are to be isolated from the vacuum pump and this pressure is to be maintained for a period of 5 min.

No internal pressure rise is permitted.

(8) Repeated assembly test

Mechanical joint test specimens are to be dismantled and reassembled 10 times in accordance with manufacturer's instructions and then subject to a tightness test as defined in 1.5.5(1).

Appendix 4 AIR PIPE CLOSING DEVICES

1.1 *General requirements*

1.1.1 Where air pipes are required by the Rules or the International Convention on Load Lines, 1966 or the Protocol of 1988 relating to the International Convention on Load Lines, 1966 to be fitted with automatic closing devices, they are to comply with the following.

1.2 *Design*

1.2.1 Air pipe automatic closing devices are to be so designed that they will withstand both ambient and working conditions, and be suitable for use at inclination up to and including ±40°.

1.2.2 Air pipe automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

1.2.3 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cage or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled.

1.2.4 Air pipe automatic closing devices are to be self-draining.

1.2.5 The clear area through an air pipe closing device in the open position is to be at least equal to the area of the inlet.

1.2.6 An automatic closing device is to:

(1) prevent the free entry of water into the tank;

(2) allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank.

1.2.7 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim as specified in 1.2.1 of this Appendix.

1.2.8 The maximum allowable tolerances for wall thickness of floats are not to exceed ±10% of thickness.

1.2.9 The inner and the outer chambers of an automatic air pipe head is to be of a minimum thickness of 6 mm. Where side covers are provided and their function is integral to providing functions of the closing device as outlined in 1.2.6 of this Appendix, they are to have a minimum wall thickness of 6 mm. Where the air pipe head meets the tightness test in 1.4.1(2) of this Appendix without the side covers attached, such side covers are not considered to be integral to the closing device, in which case their wall thickness less than 6 mm may be acceptable.

1.3 *Materials*

1.3.1 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

1.3.2 For galvanized steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 μm.

1.3.3 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminum bearing epoxy, or other equivalent, coating, applied over the zinc.

1.3.4 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to seawater and suitable for operating at ambient temperatures between -25℃ and 85℃.

1.4 *Type testing*

1.4.1 Testing of air pipe automatic closing devices

Each type and size of air pipe automatic closing device is to be surveyed and type tested at the manufacturer's works or other acceptable location according to ISC' practice. The minimum test requirements for an air pipe automatic closing device are to include the following:

(1) Determination of the flow characteristics

The flow characteristics of the air pipe closing device are to be determined. Measuring of the pressure drop versus rate of volume flow is to be carried out using water and with any intended flame or insect screens in place.

(2) Tightness test during immersion/emerging in water

An automatic closing device is to be subject to a series of tightness tests involving not less than two immersion cycles under each of the following conditions:

① The automatic closing device is to be submerged slightly below the water surface at a velocity of approximately 4 m/min and then returned to the original position immediately. The quantity of leakage is to be recorded.

② The automatic closing device is to be submerged to a point slightly below the surface of the water. The submerging velocity is to be approximately 8 m/min and the air pipe vent head is to remain submerged for not less than 5 min. The quantity of leakage is to be recorded.

③ Each of the above tightness tests is to be carried out in the normal position as well as at an inclination of 40 degrees under the strictest conditions for the device. In cases where such strictest conditions are not clear, tests are to be carried out at an inclination of 40 degrees with the device opening facing in three different directions: upward, downward, sideways (left or right), see Figures 1 to 4.

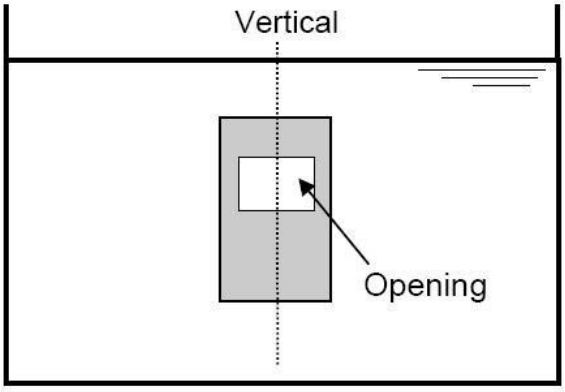


Figure 1 Example of normal position

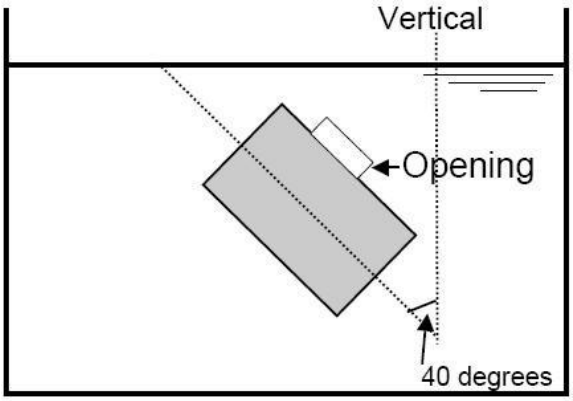


Figure 2 Example of inclination 40 degrees opening facing upward

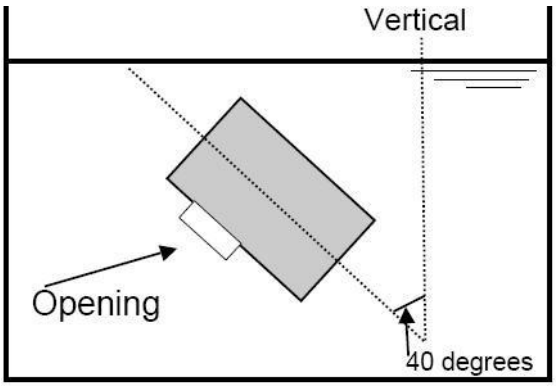


Figure 3 Example of inclination 40 degrees opening facing downward

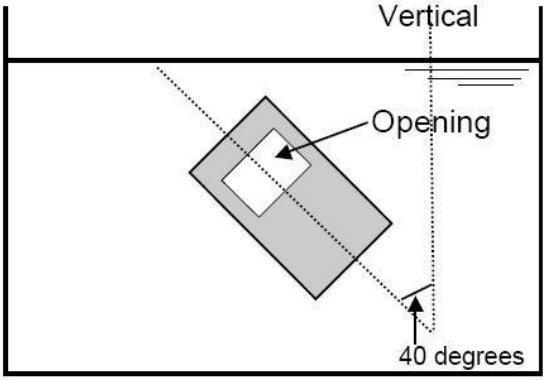


Figure 4 Example of inclination 40 degrees opening facing sideways

The maximum allowable leakage per cycle is not to exceed 2 ml/mm of nominal diameter of inlet pipe during any individual test.

(3) Discharge /reverse flow test

The air pipe head is to allow the passage of air to prevent excessive vacuum developing in the tank.

① Reverse flow test

a. A reverse flow is to be performed. A vacuum pump or another suitable device is to be connected to the opening of the air pipe leading to the tank. The flow velocity is to be applied gradually at a constant rate until the float gets sucked and blocks the flow.

b. The velocity at the point of blocking is to be recorded. 80% of the value recorded is to be stated in the certificate.

② Alternative to the reverse flow test

a. For pipe heads of 400 mm nominal diameter and above, as an alternative to the reverse flow test, a numerical simulation test based on computational fluid dynamics (CFD), to be carried out in conjunction with limited representative testing to establish the validity of the CFD modelling and results, may be accepted;

b. CFD predictions for air pipe heads can be validated against the available actual reverse flow test results of same size and type of air pipe heads;

c. The accuracy of the CFD modelling and the major assumptions used for the calculation are to be documented;

d. Mesh convergence studies are to be carried out and documented; and

e. The requirement as per the preceding ①b applies.

1.4.2 Testing of non-metallic floats

Impact and compression loading tests are to be carried out on the floats before and after pre-conditioning as shown in Table 1.4.2.

Pre-conditioning of test *Table 1.4.2*

Test condition \ Test temperature (℃)	-25	20	85
Dry	×	×	×
After immerging in water	×	×	×
After immerging in fuel oil	–	×	–
Immerging in water and fuel oil is to be for at least 48 h			

Abbreviations: × test is required
– test is not required

(1) Impact test

The test may be conducted on a pendulum type testing machine. The floats are to be subjected to 5 impacts of 2.5 Nm each and are not to suffer permanent deformation, cracking or surface deterioration at this impact loading.

Subsequently the floats are to be subjected to 5 impacts of 25 Nm each. At this impact energy level some localized surface damage at the impact point may occur. No permanent deformation or cracking of the floats is to appear.

(2) Compression loading test

Compression tests are to be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which it is intended that float is to be used.

For ball type float, loads are to be applied through a concave cap of the same internal radius as the test float and bearing on an area of the same diameter as the seating.
For a disc type float, loads are to be applied through a disc of equal diameter as the float.
A load of 350 kg is to be applied over one minute and maintained for 60 min. The deflection is to be measured at intervals of 10 min after attachment of the full load. The record of deflection against time is to show no continuing increase in deflection and, after release of the load, there is to be no permanent deflection.

1.4.3 Testing of metallic floats

Tests are to be conducted in accordance with 1.4.2(1). The tests are to be carried out at room temperature and in the dry condition.

CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS

Section 1 GENERAL PROVISIONS

3.1.1 *Application*

3.1.1.1 The requirements of this Chapter apply to piping and ventilating systems on ships except where otherwise stated.

3.1.2 *Materials*

3.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

3.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see Section 4 of Chapter 2 of this PART.

3.1.3 *Plans and documents*

3.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

Section 2 DRAINAGE OF COMPARTMENTS, OTHER THAN MACHINERY SPACES

3.2.1 *General requirements*

3.2.1.1 All ships are to be provided with efficient bilge pumping systems capable of pumping from and draining any watertight compartment, other than a space permanently appropriated for the carriage of fresh water, water ballast, oil fuel or liquid cargo, and any other space where efficient means of pumping are available under all practical conditions. For particular compartments, if the survival capability and the safety of the ship are not impaired by flooding of the compartments, bilge pumping arrangements may be dispensed with.

Efficient means are to be provided for draining water from insulated holds. For their particular requirements, see relevant provisions specified in Chapter 3 of PART FIVE of the Rules.

3.2.1.2 The suctions and means for drainage are to be so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.2.1.3 In passenger ships, the bilge pumping plant is to be capable of draining any one watertight compartment which is neither a permanent oil compartment nor a permanent water compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.2.2 *Cargo holds*

3.2.2.1 The bilge suctions in cargo holds are to be arranged in accordance with Table 3.2.2.1.

Bilge suction arrangements in cargo holds *Table 3.2.2.1*

Cargo holds condition		Suction arrangement in each cargo hold
Without double bottom	Bottom shell slopping down to the center line ≥ 5°	One near center line at after end
	Bottom shell slopping down to the center line < 5°	One on each side at after end
With double bottom	Inner bottom plating extending to ship's side and forming bilges at the wings	One on each side

Cargo holds condition		Suction arrangement in each cargo hold
	Inner bottom slopping down to the center line	One near center line
	Inner bottom plating extending to ship's side and not forming bilge	One bilge well with suction on each side
In ships having only one hold, and the length of the hold exceeds 35 m		Fitted in forward half-length and after half-length of the hold
In narrow holds at the ends of ships		One near center line

3.2.2.2 Enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship

Drainage arrangement of enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship may discharge in the form of gravity drainage by means of scupper according to the following requirements:

(1) Where the freeboard to the bulkhead deck or the freeboard deck, respectively, is such that the deck edge is immersed when the ship heels more than 5°, the drainage is to be by means of a sufficient number of scuppers of suitable size discharging directly overboard.

The arrangement of such scupper pipes is to be in accordance with the requirements of regulation 22, Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

(2) Where the freeboard is such that the edge of the bulkhead deck or the edge of the freeboard deck, respectively, is immersed when the ship heels 5° or less, the drainage of the enclosed cargo spaces on the bulkhead deck or on the freeboard deck, respectively, is to be led to a suitable space, or spaces, of adequate capacity, having a high water level alarm and provided with suitable arrangements for discharge overboard.

(3) Scuppers are to be provided at both port and starboard. The number and disposition of the scuppers are such as to prevent unreasonable accumulation of free water. Grills are to be provided at the open end of the scupper and the scuppers are not to be less than 100 mm in diameter.

(4) Where the enclosed cargo space is protected by a fixed pressure water-spraying fire-extinguishing system, the pumping arrangements are to take into account the requirements for any fixed pressure water-spraying fire-extinguishing system.

(5) Where the enclosed cargo space is protected by a carbon dioxide free-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

(6) Water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present.

3.2.3 *Holds and deep tanks for alternative carriage of liquid or dry cargo*

3.2.3.1 Where the inner bottom is slopping down to the centre line with an angle of not less than 5°, one centre suction only will be accepted and the wing suctions may be omitted.

3.2.3.2 In holds and deep tanks for alternative carriage of liquid or dry cargo, the liquid cargo and water ballast filling and suction pipes are to be provided with blanking flanges or other equivalent means, also the bilge suction pipes are to be provided with blanking flanges in way of the bulkheads, so as to isolate the filling and suction pipes when the hold or tank is being used for the carriage of dry cargo, and to isolate the bilge suction pipes when the hold or tank is being used for the carriage of liquid cargo or water ballast.

3.2.4 *Fore peaks, after peaks and cofferdams*

3.2.4.1 Where the peaks are used as dry compartments, the drainage of both peaks is to be effected either by a power pump branch bilge suction or a hand pump suction. In the latter case, the suction lift is in no case to exceed 7 m.

3.2.4.2 Suitable drainage arrangements are to be provided in cofferdams.

3.2.5 *Spaces above fore peaks, after peaks and machinery spaces*

3.2.5.1 The chain locker and the watertight compartments above the fore peak tank are to be drained by hand pump or power pump bilge suctions. Other effective means of drainage are also acceptable.

3.2.5.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be drained either by hand pump or power pump bilge suctions. Such compartments may also be drained by scuppers of not less than 38 mm bore, discharging to the shaft tunnels (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks or shut-off valves situated in well lighted and easily visible positions.

3.2.6 *Shaft tunnel and pipe tunnel*

3.2.6.1 The shaft or pipe tunnel is, in general, to be drained by a branch bilge suction at the after end of

the tunnel. Where water might accumulate at the forward end of the tunnel or the length of the tunnel is more than 35 m, additional bilge suction is required.

Section 3 BILGE DRAINAGE OF MACHINERY SPACES

3.3.1 *General requirements*

3.3.1.1 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be branch bilge suction, and the other is to be direct bilge suction.

3.3.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

3.3.2 *Bilge suction arrangements in machinery spaces*

3.3.2.1 The bilge suctions in machinery spaces are to be arranged in accordance with Table 3.3.2.1.

Bilge suction arrangements in machinery spaces *Table 3.3.2.1*

Condition of machinery spaces		Branch bilge suction	Direct bilge suction
Main engine room with single bottom	Bottom shell slopping down to the center line ≥ 5°	One near center line	One near center
	Bottom shell slopping down to the center line < 5° and all passenger ships	One near center line and one on each side	One near center
Main engine room with double bottom	Inner bottom extends the full length of the machinery space and forms bilges at the wings	One on each side	One on each side
	Inner bottom extends the full length and breadth of the machinery space	One bilge well with one suction on each side	One bilge well with one suction on each side
Ships with propelling machinery aft		One on each side at the fore end and one at central longitudinal plane at aft end	One on each side at the fore end of engine room
Boiler room or auxiliary engine room separated from the main engine room by watertight bulkheads; separate motor room of electrically propelled ships		Same as for cargo holds	At least one for each watertight compartment

3.3.2.2 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crank-pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

3.3.2.3 In ships propelled by electrical machinery, in addition to the branch bilge suctions and direct bilge suctions arranged appropriate to the conditions of machinery space, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

3.3.2.4 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided, there is to be at least one suction on each side of the space.

3.3.3 *Emergency bilge suctions of machinery spaces*

3.3.3.1 In addition to the bilge suctions required in 3.3.2.1 to 3.3.2.4 of this Section, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to a main cooling water pump and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is 450 mm above the bottom platform.

3.3.3.2 In ships with steam propelling machinery, the emergency suction is to have a diameter of at least 2/3 that of the main circulating pump suction. In other ships, the diameter of suction is not to be less than the diameter of the pump suction.

3.3.3.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest power pump which is not a bilge pump. This pump is to have a capacity not less than that required for a bilge pump, and the bilge suction is at least to be the same size as that of the pump suction branch.

Where the pump to which the emergency bilge suction is connected is of the self-priming type, the direct bilge suction on the same side of the ship may be omitted, except in passenger ships.

3.3.3.4 Emergency bilge suction valves are to be provided with permanent nameplates clearly indicating

their purpose.

Section 4 BILGE PUMPS AND BILGE PIPING

3.4.1 *Number of bilge pumps*

3.4.1.1 The number of power bilge pumps for each ship is to comply with the requirements of Table 3.4.1.1.

Number of power bilge pumps *Table 3.4.1.1*

Ship type, navigation area and parameters			Independent power pump	Power pump driven by main engine or independent power pump
Passenger ship	Passenger ships engaged on international voyages; Passenger ships with service category 1 and upper than category 1; Passenger ships carrying more than 500 passengers with service category 2;	Bilge pump numeral ≥ 30	3	1
		Bilge pump numeral < 30	2	1
	Passenger ships other than those listed above		2	1
Ships other than passenger ship		Ship's length > 91.5m	2	–
		Ship's length ≤ 91.5m	1	1

3.4.1.2 Each bilge pump prescribed in 3.4.1.1 of this Section may be substituted by a pumping unit consisting of several pumps. The total capacity of each pumping unit is not to be less than the capacity of a bilge pump specified in 3.4.2.4 of this Section.

3.4.1.3 Independent power sanitary, ballast and general service pumps may be accepted as independent power bilge pumps, provided they are of the required capacity of the self-priming type or with the self-priming arrangement and connected to the bilge main.

3.4.1.4 For ships other than passenger ships, an ejector with an adequate pressure of water supply from a sea water pump and connected to the bilge piping may be accepted as an independent power bilge pump.

3.4.1.5 For passenger ships, the bilge pump numeral C is to be calculated as follows:

when P_1 is greater than P: $C = \frac{72(M + 2P_1)}{V + P_1 - P}$

in other cases: $C = \frac{72(M + 2P)}{V}$

where:

M — the volume of the machinery space, in m^3, as defined in SOLAS regulation II-1/2, that is below the bulkhead deck; with the addition thereto of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and forward of, or abaft, the machinery space;

V— the whole volume of the ship below the bulkhead deck, in m^3;

P— the whole volume of the passenger and crew spaces below the bulkhead deck, in m^3, which are provided for the accommodation and use of passengers and crew, excluding baggage, store, provision and mail rooms;

$$P_1 = KN$$

where:

N — the number of passengers for which the ship is to be certified; and

$K = 0.056L$

where:

L — the length of the ship, in m, as defined in SOLAS regulation II-1/2.

However, where the value of KN is greater than the sum of P and the whole volume of the actual passenger spaces above the bulkhead deck, the figure to be taken as P_1 is that sum or two-thirds KN, whichever is the greater.

3.4.2 *Type and capacity of bilge pumps*

3.4.2.1 All power bilge pumps are to be of the self-priming type, or with the self-priming arrangements.

3.4.2.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type, or with self-priming arrangements.
3.4.2.3 Each power bilge pump is to be capable of giving a speed of water through the required main bilge pipe of not less than 2 m per second.
3.4.2.4 The capacity of each bilge pump (Q) is not to be less than the value calculated by the following formula:

$$Q = 5.66\, d_1^2 \times 10^{-3} \quad \text{m}^3/\text{h}$$

where: d_1 — internal diameter of bilge main, obtained from the formula in 3.4.3.1 of this Section, in mm.
3.4.2.5 In ships other than passenger ships, where one bilge pump is of slightly less than the rule capacity, the deficiency may be made good by an excess capacity of the other pumps. In general, this deficiency is to be limited to 30%.

3.4.3 *Bilge pipe systems*

3.4.3.1 The internal diameter d_1 of the bilge main is to be calculated according the following formula. However, the actual internal diameter of the bilge main may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_1 = 25 + 1.68\sqrt{L(B + D)} \quad \text{mm}$$

where: L — length of ship, in m (measured between perpendiculars taken at the extremities of the deepest subdivision load line).
Where the engine room bilge pumps are fitted primarily for serving the engine room and they do not serve cargo space bilges, L may be reduced by the combined length of the cargo tanks or cargo holds. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines;
B — breadth of ship, in m (the extreme width from outside of frame to outside of frame at or below the deepest subdivision load line).
D — molded depth of ship to bulkhead deck, in m.
When the bilge of enclosed cargo spaces situated on the bulkhead deck or freeboard deck is drained by means of bilge system, D is to be selected according to following requirements:
(1) when the enclosed cargo space extends for the full length of the ship, D is to be measured to the next deck above the bulkhead deck;
(2) where the enclosed cargo spaces cover a lesser length, D is to be taken as the molded depth to the bulkhead deck plus lh/L, where l and h are the aggregate length and height respectively of the enclosed cargo spaces.

3.4.3.2 In no case is the internal diameter of the bilge main to be less than that required for the largest branch bilge line.
3.4.3.3 The internal diameter d_2 of branch bilge suction pipes fitted in cargo and machinery spaces is not to be less than the value determined by the following formula, but the actual internal diameter of branch bilge suction pipes may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_2 = 25 + 2.15\sqrt{l(B + D)} \quad \text{mm}$$

where: l — length of compartment, in m;
B— breadth of ship, in m;
D— molded depth of ship to bulkhead deck, in m.
3.4.3.4 In general, no branch bilge suction pipe is to be less than 50 mm bore.
3.4.3.5 In no case is the internal diameter of the direct bilge suction to be less than that required for the main bilge line.
3.4.3.6 The branch bilge suction pipe to the tunnel well is, in general, not to be less than 65 mm bore.
3.4.3.7 The section area of each branch pipe connecting the bilge main to a distribution chest is not to be less than the sum of the areas required for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

3.4.4 *Bilge pumps and pipe connections*

3.4.4.1 The connections at the bilge pumps are to be such that at least one of the pumps may continue in operation when the other pumps are being opened up for overhaul.
3.4.4.2 The arrangements of pump and pipelines are such that the working of any of the pumps so

connected is unaffected by the other pumps being in operation at the same time.
3.4.4.3 All bilge suction pipes are to be independent of other piping up to the bilge pump suction valve chest.

3.4.5 *Non-return arrangements*
3.4.5.1 For the purpose of preventing the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks, screw-down non-return valves are to be provided in the following fittings:
(1) bilge valve distribution chests;
(2) bilge suction hose connection, whether fitted direct to the bilge pump or on the main bilge line;
(3) direct bilge suctions;
(4) bilge pump connections to main bilge line.

3.4.6 *Blanking arrangements*
3.4.6.1 In the case of deep tanks and cargo holds which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank or hold is being used for the carriage of dry cargo, and for blank flanging the bilge suction pipes when the tank or hold is being used for the carriage of water ballast.
For arrangement when oil fuel or cargo oil (having a flash point above 60°C) is carried in deep tanks, see 4.2.9.1 of this PART.

3.4.7 *Bilge pipes in way of deep tanks and double bottom tanks*
3.4.7.1 In way of deep tanks, bilge pipes are preferably to be led through pipe tunnels but, where this is not done, the pipes are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART, with welded joints or other reliable joints. The number of joints is to be kept to a minimum.
3.4.7.2 Expansion bends, not glands, are to be fitted to these pipes within the deep tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the approved type.
3.4.7.3 Bilge suction pipes are not to be led through double bottom tanks as far as practicable. Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART.
3.4.7.4 Expansion bends, not glands, are to be fitted to these pipes within the double bottom tanks.
3.4.7.5 The pipes are to be tested after installation, to a pressure not less than that required for the deep or double bottom tanks through which they pass.

3.4.8 *Bilge fittings*
3.4.8.1 Where the inner bottom plating in machinery spaces or cargo holds extends to the ship's side and does not form bilges, the bilge suctions are to be arranged in bilge wells. The bilge wells are to be formed of steel plates and are not to be less than 0.15 m^3 in capacity.
3.4.8.2 Each branch bilge suction and each direct bilge suction in machinery spaces and tunnels (excluding emergency suctions) are to be led from easily accessible mud boxes fitted with straight tail pipes to the wells or bilges. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.
3.4.8.3 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The strum boxes are to be so constructed that they can be easily removed and replaced for cleaning.
3.4.8.4 Bilge valves, cocks and mud boxes are as far as possible to be fitted at, or above, the machinery space and tunnel platforms. Where they are situated just below the platform, provided readily removable traps or covers are to be fitted, and nameplates are to be fitted to indicate the presence of these fittings.

3.4.9 *Miscellaneous*
3.4.9.1 The design, construction and arrangement of sludge tanks and standard discharge connections are to comply with the provisions of relevant international conventions.
3.4.9.2 Bilge piping systems are to be so arranged as to meet the relevant requirements for the prevention of pollution from ships.

Section 5 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE FOR PASSENGER SHIPS

3.5.1 *Arrangement of bilge pumps and bilge main*

3.5.1.1 In passenger ships the required power bilge pumps are to be placed, if practicable, in separate watertight compartments. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

3.5.1.2 In passenger ships of 91.5 m or more in length, or having a bilge pump numeral of 30 or more, the arrangements are to be such that at least one of the power bilge pumps will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:

(1) one of the pumps is a reliable emergency pump of a submersible type having its source of power situated above the bulkhead deck;

(2) the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required to withstand, at least one pump in an undamaged compartment will be available.

3.5.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than *B*/5 (*B* being the breadth of ship), measured at right angles to the centreline at the level of the deepest subdivision load line.

3.5.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the *B*/5 line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the *B*/5 line.

3.5.2 *Arrangement of bilge pipes*

3.5.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than *B*/5 or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5.2.2 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be in positions which are accessible at all times under ordinary circumstances. They are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. In addition, damage to a pump or its pipe connecting to the bilge main situated outboard of *B*/5 line is not to put the bilge system out of action. If there is only one system of pipes common to all the pumps, the necessary cocks or valves for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system, and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case only the cocks and valves necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

3.5.2.3 All cocks and valves mentioned in 3.5.2.2 of this Chapter which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

Section 6 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE

3.6.1 *Additional requirements for bilge drainage for oil tankers*

3.6.1.1 For the additional requirements for bilge drainage for oil tankers, see relevant provisions of Section 3, Chapter 5 of this PART.

3.6.2 Additional requirements for bilge drainage for spaces using fixed pressure water-spraying fire-extinguishing systems①

3.6.2.1 Pumping and drainage facilities are to be provided in spaces using fixed pressure water-spraying fire-extinguishing systems for draining large quantities of water accumulation on the deck or tank top on consequence of the operation of the fixed pressure water-spraying system, and following requirements are

① Refer to MSC.1/Circ.1320: Guidelines for the Drainage of Fire-fighting Water from Closed Vehicle and Ro-Ro Spaces and Special Category Spaces of Passenger and Cargo Ships.

to be complied with.

(1) For passenger ships:

① In the spaces above the bulkhead deck, scuppers complying with relevant requirements of MSC.1/Circ.1320 are to be fitted so as to ensure that such water is rapidly discharged overboard. Discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements of regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, are to be kept open while the ships are at sea.

② In the spaces below the bulkhead deck, pumping and drainage facilities complying with relevant requirements of MSC.1/Circ.1320 may be required to be provided additional to the requirements of Section 2 to Section 5 of this Chapter. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

(2) For cargo ships:

The drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces and comply with relevant requirements of MSC.1/Circ.1320. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account in its approval of the stability information. Such information is to be included in the stability information supplied to the master as required.

3.6.2.2 On all ships, for closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means are to be provided to prevent the blockage of drainage arrangements and relevant requirements of MSC.1/Circ.1320 are to be complied with.

3.6.3 *Additional requirements for bilge drainage for periodically unattended machinery spaces*

3.6.3.1 For the additional requirements of bilge drainage for periodically unattended machinery spaces, see relevant provisions of 3.9.2 of Chapter 3 in PART SEVEN of the Rules.

3.6.4 *Additional requirements for bilge drainage for unattended other machinery spaces*

3.6.4.1 Bilge level alarms are to be provided for unattended other machinery spaces below waterline (e.g. athwartship thruster space, emergency fire pump space, etc.).

Section 7 DRAINAGE ARRANGEMENTS AND BALLAST PIPING FOR NON-SELF-PROPELLED SHIPS

3.7.1 *General requirements*

3.7.1.1 Non-self-propelled ships are to be provided with means for drainage of all watertight compartments which give contribution to the vessel's buoyancy and floatability (except for compartments permanently used to carry liquid).

3.7.1.2 This Section is the additional requirements to drainage arrangements and ballast piping for non-self-propelled ships. With the exemption specified in the following, the rules and principles for drainage of ship with propulsion machinery are to be referred to.

3.7.2 *Pierhead pontoon and non-self-propelled ships without auxiliary power*

3.7.2.1 For pierhead pontoon and non-self-propelled ships without auxiliary power, at least two portable hand pumps are to be fitted to permit the efficient drainage of each compartment. Suitable access hatches for the pumping equipment are to be provided for each compartment.

3.7.2.2 The internal diameter d of the hand pump suction is not to be less than the value determined by the following formula:

$$d = 0.01T + 50 \quad \text{mm}$$

where: T — tonnage under upper deck, in t.

Where the ship is subdivided into small watertight compartments, 50 mm bore suction will be accepted. The internal diameter of the water cylinder of piston pumps is not to be less than twice the required diameter of the suction.

3.7.3 *Manned non-self-propelled ships with auxiliary power*

3.7.3.1 In non-self-propelled ships with auxiliary power, permanently installed bilge system with power bilge pumps are to be provided for dealing with the drainage of tanks and principal compartments.

3.7.3.2 Manned ships with auxiliary power for unlimited service are to be equipped with two power driven bilge pumps.

3.7.3.3 Manned ships with auxiliary power for limited service may have one power driven bilge pump, but in this case, the bilge pump is not to serve as fire pump.

3.7.3.4 All compartments required to be equipped with bilge drainage arrangements are to have branch bilge suction connected with bilge system.

3.7.3.5 In addition to branch bilge suction, a direct bilge suction to bilge pump is to be provided for the engine room.

3.7.3.6 Dry compartments in fore and aft peak may be drained by hand pumps.

3.7.3.7 Rooms situated on deck may be drained directly overboard.

3.7.4 *Unmanned non-self-propelled ships with auxiliary power*

3.7.4.1 Unmanned ships with auxiliary power are to be provided with a power driven bilge pump.

3.7.4.2 Any engine room or pump room is to have bilge suctions to power bilge pump.

3.7.4.3 Other compartments may be drained by portable pumps. Suitable access hatches for the pumping equipment are to be provided for each compartment.

3.7.5 *Ballast system of non-self-propelled ships*

3.7.5.1 For non-self-propelled ships fitted with ballast tank, each ballast tank is to be provided with ballast system connected by pipes.

3.7.5.2 Pierhead pontoon and non-self-propelled ships without auxiliary power may permit to use a portable pump as ballast pump.

3.7.5.3 Non-self-propelled ships with auxiliary power are to be provided with at least one power driven ballast pump.

Section 8 BALLAST AND SCUPPER SYSTEMS

3.8.1 *Ballast piping*

3.8.1.1 The arrangement of ballast piping and the number of suctions are to be such that any ballast tank can be filled or emptied under normal service conditions, whether the ship is upright or listed.

3.8.1.2 Where the ballast tanks exceed 35 m in length, they are normally to be fitted with bilge suctions at their forward and aft ends.

3.8.1.3 The arrangement of ballast piping is to be such as to prevent the possibility of water passing from the sea or from ballast tanks into dry cargo and machinery spaces or other dry compartments.

3.8.1.4 Ballast water pipes are not to pass through drinking water, boiler feed water or lubricating oil tanks. Where it is unavoidable, the wall thickness of ballast pipes in drinking water, feed water or lubricating oil tanks is to comply with the provisions of column 5 in Table 2.2.2.6(1) of this PART and welded joints are to be adopted. Ballast water pipes passing through a pipe tunnel may also be an option.

3.8.1.5 The ballast piping is not to be in connection with the bilge pipes from dry cargo and machinery spaces, nor with the pipes from oil tanks. However, this requirement need not be applied to the pipes located between distribution boxes and pump suctions or between pumps and overboard discharges, nor to the pipes described in 3.8.1.6 below.

3.8.1.6 Where the compartments (including deep tanks) are used for alternative carriage of dry cargo or oil or ballast water, provision is to be made for isolating or blank flanging the ballast lines. This requirement is also applicable to the drinking water tanks which may be used as ballast tanks, so as to avoid the interconnection of the two systems. The arrangement for the discharge of oily ballast water is to be in accordance with the relevant requirements for the prevention of pollution from ships.

3.8.1.7 Alternate loading of fuel oil and ballast water is to comply with the relevant requirements of 4.2.9, Chapter 4 of this PART.

3.8.1.8 For the requirements of ballast system in oil tankers, see the relevant provisions in Section 3, Chapter 5 of this PART.

3.8.2 *Scuppers and sanitary discharges*

3.8.2.1 For the requirements of scuppers and sanitary discharges, see the relevant requirements specified

in regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

3.8.2.2 The installation of all suction and discharge valves or side standpipes on scuppers and sanitary discharges that are secured direct to the shell plating of the ship is to be in compliance with the relevant requirements of 2.8.9.2 of this PART.

Section 9 REMOTELY CONTROLLED BILGE AND BALLAST SYSTEMS

3.9.1 *Arrangement*

3.9.1.1 If a main bilge line outside engine room is provided, its arrangement is to satisfy either of the following requirements:

(1) If there is only one main bilge line and a pipe tunnel is provided, it is to be placed in the pipe tunnel, and as high as possible in the pipe tunnel. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves.

(2) If there is only one main bilge line and a pipe tunnel is not provided, the main is to be placed in a space that is not prone to mechanical damage, such as double bottom ballast tanks and void tanks, etc. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves and the valves are to be located in an accessible dry compartment.

(3) If there are two main bilge lines, each cargo hold is provided with a branch bilge suction connected to each main bilge line respectively, and remotely controlled valves are fitted on each branch bilge suction line.

3.9.1.2 The main bilge line for cargo holds is to be dimensioned as the machinery spaces main bilge line.

3.9.1.3 The main bilge line for cargo holds is to be fitted with a shut-off valve in the machinery spaces.

3.9.2 *Valves*

3.9.2.1 The remotely controlled valves in branch bilge suction lines are to be screw-down non-return valves or shut-off and non-return valves connected in series.

3.9.3 *Pumps*

3.9.3.1 Operating indications of the remotely controlled bilge and ballast pumps are to be provided at the remote control panel.

Section 10 AIR, OVERFLOW AND SOUNDING PIPES

3.10.1 *General requirements*

3.10.1.1 The cargo mentioned in this Section is the oils having a flash point above 60℃(closed cup test).

3.10.1.2 Air, overflow and sounding pipes are to be made of steel or other approved material.

3.10.1.3 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

3.10.1.4 In addition to complying with the requirements of this Section, air pipes are to be in compliance with the relevant provisions in 1.12.7.5 of PART TWO of the Rules.

3.10.2 *Arrangement of air pipes*

3.10.2.1 Air pipes are to be provided for tanks intended to carry water, oil fuel and lubricating oil, and also for cofferdams and pipe tunnels. The shaft tunnel is to be provided with air pipes if necessary. Air pipes are to be fitted at the highest part of the tanks and far apart from the filling pipes.

3.10.2.2 Tanks having top plates not less than 7 m either in length or in width are to be provided with two or more air pipes arranged suitably apart. Where such arrangements are impracticable due to special circumstances, one air pipe is acceptable provided that effective venting is guaranteed. Where the tank top is of unusual or irregular profile, the number and positions of the air pipes will be decided in each case.

3.10.2.3 Tanks with cathodic protection are to have air pipes fitted forward and aft.

3.10.2.4 All double bottom tanks are to be fitted with air pipes. The double bottom tanks extending from side to side of the ship are to be fitted with air pipes led from both sides. For the double bottom tanks with less breadth at the ship's bow and stern, however, only one vent pipe may be fitted, provided that this single pipe can ensure the effective venting.

3.10.2.5 Location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are

to be such that in the event of a broken vent pipe this will not directly lead to the risk of ingress of seawater splashes or rainwater.
3.10.2.6 The arrangement of the air piping is to be such that in the event of any one of the tanks being damaged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes.

3.10.3 *Termination of air pipes*

3.10.3.1 Air pipes to the following tanks and cofferdams are to be led to the open above the freeboard deck:
(1) fuel oil tanks;
(2) cargo tanks;
(3) heated lubricating oil tanks and hydraulic oil tanks;
(4) tanks, situated outside machinery spaces, which are not fitted with overflow pipes and can be pumped up;
(5) cofferdams adjacent to fuel oil tanks or cargo tanks.
3.10.3.2 Air pipes to the following tanks and cofferdams other than those prescribed in 3.10.3.1 of this Section are to be led to above the bulkhead deck:
(1) double bottom tanks;
(2) deep tanks extending to shell plating;
(3) tanks which can be directly flooded from the outboard and seawater case;
(4) other cofferdams.
3.10.3.3 Air pipes from lubricating oil tanks or fuel oil draining tanks with a volume less than 0.5 m^3 and which cannot be pumped up may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.
3.10.3.4 The open ends of air pipes to oil fuel and cargo tanks are to be situated on the open deck where no danger will be incurred from issuing oil or vapor.
3.10.3.5 The open ends of air pipes to oil fuel and cargo tanks are to be furnished with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.
3.10.3.6 The wire gauze diaphragm at the open ends of air pipes is to have a clear area not less than the cross-sectional area required for the air pipe.

3.10.4 *Size of air pipes*

3.10.4.1 In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to each tank is not to be less than 25% greater than the effective area of the respective filling pipes. In any case, the internal diameter of air pipes is not to be less than 50 mm. When an air pipe serves several tanks, the sectional area of the air pipe is to be at least the combined area of the largest air pipes for two tanks.
3.10.4.2 Where overflow pipes are fitted as specified in this Section, the sectional area of the air pipes is to be at least 20% of that of the filling pipes.
When an air pipe serves several tanks all having overflow pipes as specified in this Section, the sectional area of the air pipe is to be at least 20% of the combined area of the two largest filling pipes for the separate tanks.
3.10.4.3 For ships navigating in ice, the cross-sectional area of air pipes is to be adequately increased.
3.10.4.4 Where tanks form part of the structure of the ship, the wall thickness of air pipes is to comply with Table 2.2.2.6(1) of this PART.
3.10.4.5 Air pipes to shaft tunnels and pipe tunnels are to have an internal diameter not less than 75 mm.

3.10.5 *Arrangement of overflow pipes*

3.10.5.1 All tanks which can be pumped up are to be fitted with overflow pipes, when the liquid pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable, or when the sectional area of the air pipe is less than that required in 3.10.4.1 of this Section. When an air pipe serves several tanks, the air pipe of one tank is not to be considered as the overflow pipe of another tank, except the shared overflow pipe connected to the overflow tank.
3.10.5.2 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.
Overflow pipes from tanks, other than oil fuel and lubricating oil tanks, are to be led to the open or to suitable overflow tanks.
3.10.5.3 A well illuminated sight glass is to be provided in the overflow pipe, and placed on the vertical pipes in readily visible positions, or alternatively, an alarm device is to be provided to give warning either

when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.
3.10.5.4 Shut-off valves or cocks are not allowed to be fitted to the overflow pipes.

3.10.6 *Size of overflow pipes*
3.10.6.1 The sectional area of overflow pipe(s) from each tank is not to be less than 1.25 times that of the filling pipe(s). When an overflow pipe serves several tanks, the sectional area of the overflow pipe is to be at least the combined area of the largest overflow pipes for two tanks.

3.10.7 *Prevention of cross flow through the overflow pipes*
3.10.7.1 Where overflows from deep tanks which are used for the alternative carriage of fuel oil, cargo oil, water ballast, or dry cargo are connected to an overflow main of other tanks, arrangements are to be made to prevent the overflowing of liquid, gases, etc. from other tanks into the deep tank carrying dry cargo, as well as to prevent the overflowing of liquid into other tanks from the deep tank carrying the liquid.

3.10.7.2 The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main.

3.10.8 *Sounding pipes*
3.10.8.1 Sounding pipes are to be provided for all tanks, cofferdams and pipe tunnels as well as the bilges or bilge wells which are not at all times readily accessible. All sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible.
The sounding pipes are to be fitted as near the suctions as practicable.
3.10.8.2 Other sounding devices may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested satisfactorily, after fitting on board.
3.10.8.3 All sounding pipes exposed to sea and weather are to be provided with permanently attached effective means of closing to prevent the free entry of water.
3.10.8.4 The bottom plating under open ended sounding pipes is to be protected by striking plates of adequate thickness and size.

3.10.9 *Short sounding pipes*
3.10.9.1 In machinery spaces and shaft tunnels where it is not practicable to extend the sounding pipes as mentioned in 3.10.8.1 of this Section, short sounding pipes extending to readily accessible positions above the platform may be fitted. The following requirements are to be complied with:
(1) Sounding pipes are to be easily accessible and are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.
(2) In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space, and are in all cases to be fitted with self-closing devices.

3.10.10 *Additional requirements to sounding pipes in fuel oil tanks*
3.10.10.1 Safe and efficient means of ascertaining the amount of oil fuel contained in any fuel oil tank are to be provided. Where sounding pipes are used, they are not to terminate in any space where the risk of ignition of spillage from the sounding pipe might rise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where it is impracticable to arrange, termination of sounding pipes in machinery spaces may be permitted on condition that the following requirements are met:
(1) an oil-level gauge is provided meeting the requirements of 3.10.10.3 of this Section;
(2) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the oil fuel in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition;
(3) the termination of sounding pipes are fitted with self-closing blanking devices and with a small-diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that oil fuel is not present. Provisions are to be made so as to ensure that any spillage of oil fuel through the control cock involves no ignition hazard.
3.10.10.2 For fuel oil tanks other than double bottom tanks, if overflow pipes satisfying requirements are fitted, when the sounding pipes are terminated in machinery spaces, only above-mentioned requirements of 3.10.10.1(2) and (3) are to be met.
3.10.10.3 Other oil-level gauges may be used in place of sounding pipes subject to the following conditions:

(1) in passenger ships, such gauges are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel;
(2) in cargo ships, the failure of such gauges or overfilling of the tank is not to permit release of fuel into the space. The use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks is permitted. The use of cylindrical gauge glasses is prohibited.

3.10.11 *Additional requirements to sounding pipes in lubricating oil tanks*

3.10.11.1 In general, means of ascertaining the amount of lubricating oil contained in any lubricating oil tank are to comply with the requirements of 3.10.10 of this Section. However, the requirements of 3.10.10.1(1) and 3.10.10.1(3) need not be applied on condition that the sounding pipes terminating in machinery spaces are fitted with appropriate means of closure.

3.10.12 *Additional requirements to sounding pipes in other flammable oil tanks*

3.10.12.1 For flammable oil tanks in spaces where means of ignition are present, means of ascertaining the amount of flammable oil contained in any flammable oil tank are to comply with the requirements of 3.10.10 of this Section.

3.10.12.2 For flammable oil tanks in other locations, if oil-level gauges are used in place of sounding pipes, at least the requirements of 3.10.10.3(2) are to be complied with.

3.10.13 *Size of sounding pipes*

3.10.13.1 Sounding pipes are not to be less than 32 mm in bore and those of heavy fuel oil tanks are not to be less than 50 mm in bore. Sounding pipes passing through compartments or spaces where the temperatures contemplated are 0℃ or below, are not to be less than 65 mm in bore.

Section 11 VENTILATION

3.11.1 *General requirements*

3.11.1.1 Machinery spaces of category A are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

Any other machinery space is to be adequately ventilated appropriate for the purpose of that machinery space. Ventilators of machinery spaces required to be continuously ventilated are to be of a height of coaming complying with the relevant requirements of 1.12.7.4(6), PART TWO of the Rules without having to fit weathertight closing appliances, so that they can be used in all weather conditions. However, where due to vessel size and arrangement this is not practicable, lesser heights for ventilator coamings may be accepted with provision of weathertight closing appliances in accordance with the requirements of 1.12.7.4(7), PART TWO of the Rules in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

3.11.1.2 All ventilator cowls for boiler rooms are to be fitted with rotating devices so that they may be turned and locked in any desired direction.

3.11.1.3 Effective means of ventilation are to be provided for all lamp-rooms, paint lockers and other compartments used for the storage of inflammable substances, explosives or where toxic or inflammable gases may accumulate.

3.11.1.4 When ventilation pipes pass through other compartments, relevant requirements on fire division and damage stability are to be complied with.

3.11.1.5 Ventilation system is to comply with the relevant requirements of PART SIX of the Rules.

3.11.2 *Ventilators*

3.11.2.1 The ventilators are to comply with the relevant requirements in 1.12.7.4, PART TWO of the Rules.

3.11.3 *Ventilator cowls*

3.11.3.1 Ventilator cowls are to be placed on the exposed deck and located as far from exhaust outlets, sky-lights and companionways as possible.

3.11.4 *Ventilation of emergency generator rooms*

3.11.4.1 The following requirements apply to ventilation louvers which can be closed for emergency generator rooms and to closing appliances where fitted to ventilators serving emergency generator rooms:

(1) Ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic / pneumatic / electric) and are to be operable under a fire condition.

(2) Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided.

(3) Power-operated ventilation louvers and closing appliances are to be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel. Power-operated ventilation louvers and closing appliances are to open automatically whenever the emergency generator is starting / in operation.

(4) It is to be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open / closed) is to be indicated at this position. Such closing is not to be possible from any other remote position.

Section 12 ADDITIONAL REQUIREMENTS TO WATER LEVEL DETECTION AND DEWATERING OF FORWARD SPACES OF BULK CARRIERS

3.12.1 *Application*

3.12.1.1 This Section applies to classed bulk carriers of 500 gross tonnage and above and engaged on international voyages. The term bulk carrier referred to in this Section means a bulk carrier as defined in Chapter XII of the SOLAS Convention.

3.12.2 *Plans and documents*

3.12.2.1 The arrangement plan of dewatering system required by this Section is to be submitted for approval.

3.12.3 *Water level detection*

3.12.3.1 For water level detection and alarm system required to be installed in cargo hold, ballast tank and dry space, see the relevant requirements in Section 19, Chapter 2 of PART FOUR of the Rules.

3.12.4 *Dewatering system*

3.12.4.1 On bulk carriers, the means for drainage and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces any part of which extends forward of the foremost cargo hold (excluding dry spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume and the chain locker), are to be capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. Where pipes serving such tanks or bilges pierce the collision bulkhead, the remote control position of valves specified in 2.8.1.3 of this PART is to comply with the requirements of this regulation.

The detailed arrangements of dewatering system are to satisfy following requirements:

(1) The enclosed spaces which are required to control dewatering system are to be accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. A position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not accepted.

(2) The dewatering arrangements are to be such that any accumulated water can be drained directly by a pump or ejector.

(3) Where the piping arrangements for dewatering closed dry spaces are connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves are to be provided to prevent the ingress of water into dry spaces. One of these non-return valves is to be fitted with shut-off isolation arrangement. The non-return valves are to be located in readily accessible positions. The valve operation is to comply with all the requirements of this paragraph.

(4) The valve is not to move from the demanded position in the case of failure of the control system power or actuator power.

(5) Positive indication is to be provided at the remote control station to show that the valve is fully open or closed.
(6) Bilge wells are to be provided with gratings or strainers that will prevent blockage of the dewatering system with debris.
(7) The dewatering arrangements are to be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use. The systems for normal operation of electric power supplies, propulsion and steering are not to be affected by the operation of the dewatering systems. It must also be possible to immediately start fire pumps and have a ready available supply of fire-fighting water and to be able to configure and use bilge system for any compartment when the dewatering system is in operation.
(8) The enclosure of electrical equipment for the dewatering system installed in any of the forward dry spaces are to provide protection to IPX8① for a water head equal to the height of the space in which the electrical equipment is installed for a time duration of at least 24 h.

3.12.5 *Dewatering capacity*

3.12.5.1 The dewatering system is to be capable of quickly and efficiently removing water that may be accumulated in this space. The pump discharge capacity Q is not to be less than the value obtained from the following formula:

$$Q = 320A \quad m^3/h$$

where: A — the cross-sectional area of the largest ventilator pipe or air pipe serving this space and leading to the exposed deck, in m^2.

① See IEC Publication 60529.

CHAPTER 4 MACHINERY PIPING SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 *Application*

4.1.1.1 Unless stated otherwise, the requirements of this Chapter apply to machinery piping systems for ships.

4.1.2 *Materials*

4.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

4.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential for the safety of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see the relevant requirements of 2.4.3 of this PART.

4.1.3 *Plans and documents*

4.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

Section 2 OIL FUEL SYSTEMS

4.2.1 *General requirements*

4.2.1.1 Oil fuels for use in ships are to comply with the relevant provisions contained in 1.2.9 of this PART.

4.2.1.2 Drip trays are to be provided under the oil tanks which do not form part of the hull structure, pumps, filters, boiler burners and all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment. Oils in the drip trays are to be drained to special sludge tanks, and if the sludge tanks are situated in double bottom tank, shut-off valves or other reliable means of isolation are to be fitted to the drain pipes to prevent sea water entering tank through drain pipes after double bottom tank is damaged. Drain pipes are to be mutual independent from the tank overflow system.

4.2.1.3 The gaskets used for joining covers and manholes of fuel oil tanks and for joining the flanges of fuel pipes are to be made of oil-proof or heat-resistant material.

4.2.1.4 For motor ships burning oil fuel which has to be purified by purifiers, two oil fuel purification units and heating units are to be provided, one of which is a standby.

4.2.1.5 The spaces in which the burning appliances of boilers and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

4.2.1.6 In addition to the local controls, the power supply to all independently driven oil fuel transfer pumps, boiler oil fuel pumps, diesel engine fuel pumps and oil separators is to be capable of being stopped from a readily accessible position outside the spaces in which they are situated.

4.2.1.7 The oil fuel systems of diesel engines for heavy oil are to be provided with immediate change-over devices for diesel oil.

4.2.1.8 Two fuel oil service tanks or equivalent arrangements, for each type of fuel used on board, necessary for propulsion and essential systems are to be provided. Each tank is to have a capacity for at least 8 h operation at sea, at maximum continuous rating of the propulsion plant and normal operating load of the generating plant associated with that tank.

The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

4.2.1.9 A service tank is a fuel oil tank which contains only fuel of a quality ready for use, i.e. fuel of a grade and quality that meet the specification required by the equipment manufacturer. A service tank is to be declared as such and not to be used for any other purpose. Use of a settling tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an “equivalent arrangement” to two service tanks. Examples of application for the most common systems are shown below:

(1) Example 1

① Requirement normally to be followed – main and auxiliary engines and boiler(s) operating with

heavy fuel oil (HFO) (one fuel ship)

HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	MDO tank For initial cold starting or repair work of engines/boiler

② Equivalent arrangement

HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	MDO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler

This arrangement only applies where main and auxiliary engines can operate with heavy fuel oil under all load conditions and, in the case of main engines, during manoeuvring.
For pilot burners of auxiliary boilers if provided, an additional marine diesel oil tank for 8 h may be necessary.

(2) Example 2

① Requirement normally to be followed – main engine(s) and auxiliary boiler(s) operating with HFO and auxiliary engine operating with marine diesel oil (MDO)

HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	MDO service tank Capacity for at least 8 h Auxiliary engine	MDO service tank Capacity for at least 8 h Auxiliary engine

② Equivalent arrangement

HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	MDO service tank Capacity for at least the highest of: • 4 h Main engine + Auxiliary engine + Auxiliary boiler, or • 8 h Auxiliary engine + Auxiliary boiler	MDO service tank Capacity for at least the highest of: • 4 h Main engine + Auxiliary engine + Auxiliary boiler, or • 8 h Auxiliary engine + Auxiliary boiler

The arrangements in (1) ② and (2) ② apply, provided the propulsion and vital systems which use two types of fuel support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

4.2.2 *Oil burning units of boilers*

4.2.2.1 Auxiliary boilers for essential services in this Chapter are those for the purpose of supplying steam to auxiliary machineries as to ensure safe navigation of ships.

4.2.2.2 Main boilers and auxiliary boilers for essential services and for heating of heavy fuel oil are to have not less than two oil supply units, each unit generally comprising a pressure pump, a filter and a heater (if needed). The capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action. Where an exhaust gas boiler is capable of supplying steam for essential purposes, a single oil supply unit may be accepted. For a composite boiler whose exhaust side can provide steam of essential services, a single oil supply unit may also be accepted.

4.2.2.3 Oil burning unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

4.2.2.4 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners.

4.2.2.5 A starting-up oil fuel unit, which does not require power from shore, is to be provided for main boilers.

4.2.2.6 Where boiler burners are provided with steam purging and/or atomizing connections, the arrangements are to be such that oil fuel cannot find its way into the steam system.

4.2.2.7 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut out.

4.2.2.8 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control. In the case of oil-fired boilers of automatic controls, the relevant requirements of PART SEVEN of the Rules are also to be complied with.

4.2.2.9 In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically, and audible and visual warnings are given. For small auxiliary top-fired boilers, this requirement may be dispensed with.
4.2.2.10 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.
4.2.2.11 For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

4.2.3 *Oil fuel pumps, filters and isolating valves*

4.2.3.1 Where an oil fuel booster pump is fitted, one main supply pump of sufficient capacity is to be provided for the main engine at its maximum continuous output and one standby pump of sufficient capacity is to be provided for normal navigation of the ship. Such a standby pump is to be independently power driven and capable of being ready for immediate use. Where two or more main engines are fitted, each with its own booster pump, only one standby pump connected ready for immediate use is needed, or alternatively, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.
4.2.3.2 Where pumps are provided for fuel valve cooling, the arrangements of standby ones are to be in accordance with 4.2.3.1 of this Section.
4.2.3.3 Oil fuel filters are to be fitted in the oil fuel supply lines to the diesel engines, and their arrangement are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.
4.2.3.4 Oil filters fitted in parallel for the purpose of enabling cleaning without distributing oil supply to engines (e.g. duplex filters) are to be provided with arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filters/filter chambers are to be provided with suitable means for venting when put into operation and depressurizing before being opened.
Valves or cocks with drain pipes led to a safe location are to be used for this purpose.
4.2.3.5 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided. Any suitable pump in connection with fuel transfer system may be accepted as the standby pump.
4.2.3.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump or other appropriate tanks, and to effectively limit the pump discharge pressure to the design pressure of the system.
4.2.3.7 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.
4.2.3.8 In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. The means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines. The means of isolation are to be capable of reliable manual closing.
4.2.3.9 The redundancy requirements for fuel oil and hydraulic oil systems and electronic control system of electronically controlled diesel engine are to comply with the relevant requirements of paragraphs 2.1.3 and 2.2.3, Appendix 2, Chapter 9 of this PART.

4.2.4 *Oil fuel piping*

4.2.4.1 Oil fuel piping is to be entirely separate from other piping systems. The arrangements are to be such that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which are used for the carriage of fresh water. Where it is necessary to connect the fuel pipes to ballast systems, they are to be fitted with blanking flanges or other effective isolating devices.
4.2.4.2 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.
4.2.4.3 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions above the working platform.
4.2.4.4 Oil fuel lines are not to be located immediately above or near units of high temperature, including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by 1.3.6.3, Chapter 1 of this PART. As far as practicable, oil fuel lines are to be arranged far apart from hot surfaces, electrical installations or other sources of ignition and are to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems is to be kept to a minimum.
4.2.4.5 Pipes conveying heated oil to boilers under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted

parts. The number of flanged joints is to be kept to a minimum. The flanges are to be machined. The jointing material is to be oil proof and impervious to oil heated to 150℃, and is to be as thin as possible. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 1.37 MPa or design pressure, whichever is the greater.

4.2.4.6 The short joining lengths of pipes to the burners from the control valves at the boiler may have threaded cone unions of robust construction.

4.2.4.7 Flexible hoses may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

4.2.4.8 Oil fuel pipes and their valves and fittings are to be of steel or other equivalent material. Nodular graphite cast iron may be used for valves under static head fitted on the outside of fuel tank walls. Grey cast iron valves may be used in oil fuel piping with design pressure of less than 0.7 MPa and design temperature of less than 60℃.

Restricted use of flexible pipes is permissible in some positions. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

4.2.5 *Oil fuel arrangements and fuel oil tanks*

4.2.5.1 As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are not to be placed in a concealed position so that defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

4.2.5.2 Every oil fuel pipe, which, if damaged, would allow oil to escape from a storage, settling or daily service tank situated above the double bottom are to be fitted with a cock or valve directly on the tank or short pipe welded to the oil tank bulkhead with a length not exceeding the value obtained from the following formula. Such valves or cocks are to be capable of being closed locally as well as cable of being closed from safe and easily accessible positions outside the spaces where these tanks are situated. In the case of tanks having a capacity of less than 0.5 m^3, remotely controlled closing devices may be omitted.

$$L = 0.8D + 80 \quad \text{mm}$$

where: L — length of short pipe, in mm;

D— outside diameter of steel pipe, in mm.

Remote shut-off control of oil fuel valves for emergency generating set and emergency fire pump is to be separated from those of other valves.

In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves on the tank are to be fitted but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

4.2.5.3 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.2.5.2 above.

4.2.5.4 Fuel oil tanks are not to be situated immediately above boilers or other highly heated surfaces. Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

4.2.5.5 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is to preferably have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces are to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A they are not to contain oil fuel having a flashpoint of less than 60℃ (closed cup test).

In general the use of free-standing fuel oil tanks is to be avoided. When such tanks are employed the use are to be prohibited in category A machinery spaces on passenger ships. Where permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank.

4.2.5.6 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.2.5.7 Drain valves or cocks fitted to the fuel oil tanks are to be of self-closing type, and suitable

provision is to be made for collecting the oily discharge.

4.2.5.8 In ships of 400 gross tonnage and above, oil is not to be carried in a forepeak tank or a tank forward of the collision bulkhead. All ships of less than 400 gross tonnage are to comply with the above mentioned provisions so far as it is reasonable and practicable.

4.2.5.9 Location of fuel tanks in cargo area on oil and chemical tankers

On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60℃ and/or toxic liquid cargoes[①] fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within nor extend partly into the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block.

They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements to hazardous area classification must however be met.

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank as shown in Figure 4.2.5.9.

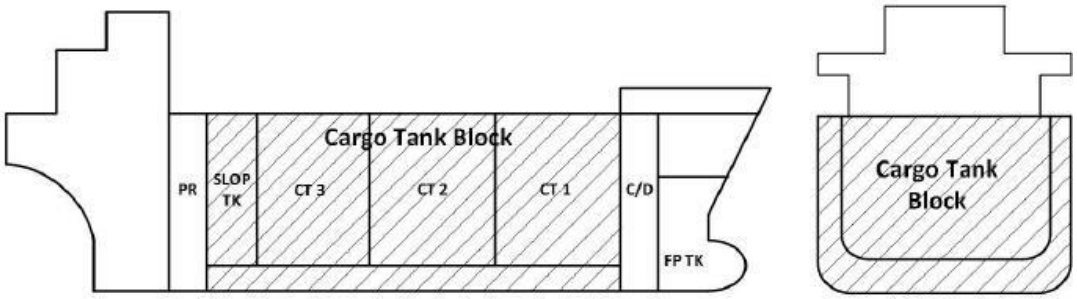


Figure 4.2.5.9

4.2.6 Filling piping

4.2.6.1 Fuel filling is to be effected by means of permanently installed lines. The filling pipes are to be led to a level as low as practicable inside the tank.

4.2.6.2 Where filling stations are fitted on board, they are to be isolated from other spaces and are to be efficiently drained and ventilated. Filling stations are to be so arranged that filling can be performed safely from both sides of the ship.

4.2.6.3 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.2.7 *Oil fuel (lubricating oil) heating*

4.2.7.1 The heating media used for oil fuel (lubricating oil) tanks, heaters or oil separators are not to be more than 220℃ in temperature. Fuel oil (lubricating oil) in storage tanks is not to be heated to temperatures within 10℃ below the flash point of the fuel oil (lubricating oil), except that where oil fuel in service tanks, setting tanks and any other tanks in supply system is heated all of the conditions in 3.2.1.5(1) to (5) of Chapter 3 of PART SIX of the Rules are satisfied.

4.2.7.2 The exhaust drains from steam or hot water pipes used for heating the oil fuel (lubricating oil) are to be led to a separate observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil.

4.2.7.3 Relief valves are to be fitted on the oil side of heaters and the discharge from the relief valves is to be led to the suction of a related pump or to a safe position.

4.2.7.4 The oil fuel pipes and oil transfer pipes intended for conveying heated oil fuel are to be provided with suitable heating means if necessary.

4.2.7.5 Oil fuel (lubricating oil) tanks in which oil is heated and heaters are to be provided with suitable means for ascertaining the temperature of the oil.

4.2.7.6 Where steam heaters or heaters using other heating media are provided in fuel or lubricating oil

① Toxic liquid cargoes include those for which toxic vapour detection is specified in column “k” of the table of chapter 17 of the IBC Code.

systems, they are to be fitted with at least a high temperature alarm or low flow alarm in addition to a temperature control, except, where the temperature dangerous for the ignition of the medium cannot be reached.

4.2.7.7 Electric heating of fuel oil or lubricating oil are to be avoided as far as practicable.

When electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In order to avoid in any case element surface temperature of 220°C and above, a safety temperature switch, independent from the automatic control sensor, is to be provided. The safety switch is to cut off the electrical power supply in the event of excessive temperature, and is to be provided with manual reset.

4.2.7.8 The exhaust gas of diesel engines is not to be directly used for heating oil fuel.

4.2.8 *Alternative carriage of oil fuel and water ballast*

4.2.8.1 In general, in oil tankers of 150 gross tonnage and above, all passenger ships and other ships of 4,000 gross tonnage and above, no ballast water is to be carried in fuel oil tanks. Where it is necessary to carry ballast water in fuel oil tanks, suitable means are to be provided for preventing pollution of the sea by oily-water ballast.

4.2.8.2 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, each settling or service tank fitted is to have a capacity sufficient to permit 12 h normal service, otherwise the suction lines of these compartments are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

4.2.9 *Deep tanks for the alternative carriage of oil, water ballast or dry cargo*

4.2.9.1 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, blank flange or other positive means of closing is to be provided for isolating the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the deep tank is used for dry cargo, and for isolating the bilge suction pipes when the deep tanks are used for oil or water ballast.

4.2.9.2 If the deep tanks are connected to an overflow system, the arrangements are to be such that liquid or vapor from other tanks cannot enter the deep tanks when dry cargo is carried in them.

4.2.10 *Separation of cargo oils from oil fuel*

4.2.10.1 Pipes conveying vegetable oils or similar cargo oils are not to be led through fuel oil tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils.

4.2.11 *Arrangements for other flammable oils*

4.2.11.1 The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board. In locations where means of ignition are present, such arrangements are at least to comply with the provisions of 4.2.4.8 and 4.2.5.4 of this Section, and with the relevant provisions contained in Section 10 of Chapter 3 of this PART.

Section 3 STEAM PIPING SYSTEMS

4.3.1 *Arrangement*

4.3.1.1 In general, steam pipes are not to be led through lamp rooms, paint lockers and cargo spaces, but where it is impracticable to avoid this arrangement, the pipes in way of cargo spaces are to be well protected from mechanical damage, and pipe joints are to be as few as practicable and preferably butt welded.

4.3.1.2 Where steam pipes subject to a working pressure exceeding 0.98 MPa are placed near to the fuel oil tank, the clearance space between the pipe and the external surface of the tank is in general to be at least 250 mm.

4.3.1.3 Steam pipes are to be arranged in visible and accessible positions in the machinery spaces. Steam pipes, except those used for preheating and sea chest blow-off services, are in general not to be led under the floor plates in machinery spaces.

4.3.1.4 Where two or more boilers are interconnected by steam pipe or pipes, a screw-down non-return valve is to be provided in the steam pipe of each boiler. Valves intended to drain condensate are to be fitted in the pipe length between these valves.

4.3.2 *Condensate drainage*

4.3.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°. Arrangements are to be made for ready access to the drain valves or cocks.

A by-pass line is to be provided where the condensate trap is installed.

4.3.3 *Thermal expansion stresses*

4.3.3.1 For steam pipes subject to a working temperature exceeding 350°C, special consideration is to be given to stress due to thermal expansion and to technique of installation.

Section 4 FEED, BLOW-OFF AND CONDENSATE SYSTEMS

4.4.1 *Feed pumps*

4.4.1.1 Two or more power driven feed pumps are to be provided for main and auxiliary boilers for essential services or steam auxiliary boilers for heating heavy oil. These feed pumps are to be of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

4.4.1.2 Forced circulation boilers are to be provided with two independently driven circulating pumps, one of which is used as a stand-by pump. For auxiliary forced circulation boilers not used for essential services, one circulating pump will be accepted.

4.4.1.3 Where a harbor feed pump is provided, it may be used for other purposes, but in no case is it to be used for oil transferring or for discharging oily bilges. Furthermore, a suitable arrangement is to be provided to prevent the contamination of feed from sea water.

4.4.2 *Feed piping*

4.4.2.1 Two feed water systems are to be provided for main and auxiliary boilers for essential services, including feed pumps. The feed systems are to be of sufficient capacity to supply feed water to the boilers with any one system out of action. Only one feed water system may be provided for steam generators heated by steam where the steam for essential services is capable of being supplied simultaneously from another sources.

Feed water systems are to be so arranged that the feed water cannot be contaminated by oil or oily water.

4.4.2.2 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, so that any pump may be shut off and opened up for overhaul.

4.4.3 *Reserve feed water*

4.4.3.1 All ships fitted with main boilers and auxiliary boilers for essential services are to be provided with tanks of sufficient capacity for reserve feed water.

4.4.3.2 For main boilers in ships, one or more evaporators of adequate capacity are to be provided to cover the losses of feed water in the system. In the case of auxiliary boilers for essential services in ships, evaporators are to be installed as necessary.

4.4.4 *Condensate pumps*

4.4.4.1 At least two power driven condensate pumps, one of which is a standby pump, are to be provided for dealing with the condensate from the main and auxiliary condensers. Independent feed pumps may be accepted as stand-by condensate pumps.

4.4.5 *Blow-off piping*

4.4.5.1 The internal diameter of the blow-off pipes is to comply with the requirements of 6.3.7.2 of this PART. Valves or cocks in the blow-off piping, situated at the ship's bottom or ship's sides, are to be arranged and constructed according to the provisions contained in 2.8.9.2 and 2.8.9.3 of this PART.

4.4.5.2 The blow-off pipes of two or more boilers may be connected to a common discharge, but the blow-off pipe for each boiler is to be fitted with a non-return valve. It is recommended that a throttle washer be fitted to the blow-off pipe.

Section 5 COOLING WATER SYSTEMS

4.5.1 *Cooling water pumps*

4.5.1.1 For motor ships, where only one main engine is fitted, a main cooling pump of sufficient capacity to maintain supply of water at the maximum continuous output of the machinery and a standby cooling pump of sufficient capacity to supply cooling water under the normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use. Where more than one main engine is fitted, each with its own cooling water pump, a complete spare pump may be accepted as a standby cooling water pump.

4.5.1.2 In steam ships, in addition to the main circulating pump for the condenser, there is to be an alternative supply from an emergency pump having a capacity sufficient to maintain the proper control of the ship (in general not to be less than 30% of that of the main circulating pump). If the main circulating pump unit consists of two independently power-driven pumps of approximately equal capacity, the emergency pump may be dispensed with.

Where a sea inlet scoop arrangement is fitted in lieu of the main circulating water pump, in addition to one independently power-driven circulating water pump having a capacity of at least 30% of that of the maximum required by circulation, a connection to the largest available pump suitable for circulation duties is to be fitted to provide the second means of circulation when the ship is maneuvering.

4.5.1.3 Where each essential auxiliary engine is fitted with a built-in cooling water pump, the standby pump may be dispensed with. If two or more auxiliary engines are supplied with cooling water from a common system, a standby cooling water pump is needed. The standby cooling water pump may be substituted by other pumps of sufficient capacity.

4.5.1.4 Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

4.5.2 *Piping and fittings*

4.5.2.1 The cooling water piping for diesel engines is to be capable of effectively regulating the inlet cooling water temperature. For closed circuit fresh water cooling system, expansion tanks are to be provided and it is recommended that an alarm for high temperature be fitted.

4.5.2.2 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge. When discharge from the relief valves is to find its way into the bilge, the valves are to be fitted in readily visible positions above the floor. The arrangement is to be such that any discharge from the relief valves will also be readily visible.

4.5.2.3 Not less than two sea inlets, which are to be fitted on both sides of the ship as far as practicable, are to be provided for the cooling water pumps of sea water cooling system or circulating system. The suction of any cooling water pump or circulating pump under normal service conditions is to be supplied from either one of the sea inlets.

4.5.2.4 Provision is to be made for the protection of all equipment cooled by sea water against corrosion.

4.5.2.5 Strainers are to be provided to the suction pipes between the sea inlets and the suctions of sea water cooling pumps. The strainers are to be so arranged that they can be cleaned without interrupting the cooling water supply.

4.5.2.6 When it is necessary, the main diesel engine with closed circuit fresh water cooling system is to be provided with suitable means for warming the engine before starting. Alternatively, means to inter-connect the fresh water cooling system for main engine to that for auxiliary engines are acceptable.

Section 6 LUBRICATING OIL SYSTEMS

4.6.1 *Lubricating oil pumps*

4.6.1.1 Main engines and their transmission gearing are to be provided with a main lubricating oil pump of sufficient capacity to maintain supply of lubricating oil at the maximum continuous output of the machinery and a standby pump of sufficient capacity to supply lubricating oil under normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use.

For ships fitted with more than one main engine, only one independently power-driven standby pump fitted is acceptable. Where each main engine and its transmission gearing is fitted with a built-in lubricating oil pump, a complete spare pump available for installation and connection may be accepted as an independently power-driven standby pump.

4.6.1.2 Where each essential auxiliary engine and its transmission gearing is fitted with a built-in lubricating oil pump, the standby pump may be dispensed with. If two or more auxiliary engines and their transmission gearing are connected to a common lubricating oil system, a standby pump is needed.

4.6.2 *Piping and fittings*

4.6.2.1 The lubricating oil piping is to be entirely separate from other piping systems. A common lubricating oil system is not to be in use for diesel engines and gear boxes.

4.6.2.2 Provision is to be made for the efficient filtration of the lubricating oil. For main propulsion machinery, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required in normal operation of ships. For generating sets, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required by generating sets under normal work load. Pressure gauges are to be fitted on both ends of lubricating oil filters or strainers. Proposals for fitting an emergency automatic by-pass device in high speed engines are to be submitted to ISC for special consideration.

Magnetic strainers are to be provided for high-powered main turbines and their reduction gears.

4.6.2.3 A relief valve is to be fitted on the lubricating oil pump discharge if the pump is capable of developing a pressure exceeding the design pressure of the system. The relief valve is to be such that the discharge oil can find its way to the suction of the pump and the pump discharge pressure is to be effectively limited to the design pressure of the system.

4.6.2.4 Visual and audible alarms are to be provided to give warning of an appreciable reduction in pressure of the lubricating oil.

4.6.2.5 Where two or more diesel engines are fitted, the drain pipes leading from the engine sumps to the lubricating oil drain tanks are to be independent to avoid intercommunication between crankcases.

4.6.3 *Additional requirements for lubricating oil systems of main turbines and main turbo-generators*

4.6.3.1 For main turbines and main turbo-generators in electrically propelled ships, a suitable emergency supply of lubricating oil is to be arranged. For this purpose, either one of the following will be accepted:

(1) The emergency supply may be obtained from a gravity tank holding sufficient lubricating oil to maintain adequate lubrication for not less than 5 min for main turbines, and, in the case of main turbo-generators, until the unloaded turbine comes to rest from the maximum rated running speed. The gravity tank is to be arranged to come automatically into use in the event of a failure of the lubricating oil pump. An alarm device is to be fitted to the gravity tank to give visual and audible warning when the oil in the tank falls to a predetermined level.

(2) The emergency supply may be obtained from a standby pump or an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the main power supply and that they are capable of coming automatically into use.

4.6.3.2 Overflow pipes, which are to be led to the lubricating oil drain tanks, are to be fitted to the gravity tanks and the cross-sectional area of the overflow pipes is not to be less than 1.25 times that of the filling pipes from the lubricating oil pumps. The overflow pipes are to be fitted with illuminated sight glasses.

4.6.4 *Lubricating oil arrangements and lubricating oil tanks*

4.6.4.1 The separation of lubricating oil tanks from adjacent tanks is to be in compliance with the requirements of 2.8.2.1 of this PART.

4.6.4.2 The capacity of lubricating oil drain tanks is to be sufficient to hold the oil in the whole system. Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drain pipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform. If the drain tanks in the double bottom are separated from the shell plating by cofferdams, the shut-off valve mentioned above may be dispensed with.

The oil inlet pipe of the drain tank is to be extended to an adequate depth below the lowest working level and is to be located as wide apart from the outlet as practicable.

4.6.4.3 The pressure lubrication systems are to comply with the requirements of 4.2.4.4, 4.2.4.8, 4.2.5.1, 4.2.5.2, 4.2.5.4 and 4.2.6.3 of this Chapter and the relevant provisions contained in Section 10 of Chapter 3 of this PART.

In the case of tanks having a capacity of less than 0.5 m^3, consideration will be given to the omission of remote controls.

If the designers confirm that an unauthorized operation of the remotely controlled closing valves on the lubricating tanks will jeopardize safe running of the main or eventful auxiliary engines, the remotely

controlled device may be omitted.
4.6.4.4 All ships are to be provided with lubricating oil storage tank(s) having an adequate capacity.
4.6.4.5 Heating of lubricating oil is to comply with the relevant requirements of 4.2.7 of this Chapter.

Section 7 HYDRAULIC TRANSMISSION PIPING SYSTEMS

4.7.1 *Materials*

4.7.1.1 All components in the hydraulic transmission piping systems are to be made of materials which are not corrodible and have no chemical reaction with the hydraulic fluid.
4.7.1.2 The hydraulic fluid is to be of high chemical stability and of good viscosity-temperature property.
4.7.1.3 Main components in hydraulic power transmission system are to be generally made of steel materials. Material test is to be carried out according to the requirements of ISC Rules for Materials and Welding.

4.7.2 *Piping*

4.7.2.1 The hydraulic transmission piping is not to be used for the lubrication of other equipment.
4.7.2.2 The strength of hydraulic pipes and fittings is to be sufficient to withstand the pressure fluctuations which might occur in the system.
4.7.2.3 Strainers and relief valves are to be provided in the hydraulic transmission piping systems. The discharge from the relief valves is in general to be led to the hydraulic fluid tanks.
4.7.2.4 Provision is to be made for de-aeration in the hydraulic piping systems and the hydraulic fluid cylinders, etc. The hydraulic piping is to be so arranged as to avoid the formation of air pockets.
4.7.2.5 Where hydraulic accumulators are provided in the hydraulic systems, overflow valves are to be fitted on the liquid side. Unless otherwise specified, for hydro-pneumatic accumulators, safety valves or fuse plugs are to be fitted on the air side, otherwise they are to be fitted in the supply pipe line, and an isolation valve is not to be provided between the air side of the accumulator and the safety valve or fuse plug.
4.7.2.6 The use of flexible hoses is to comply with the relevant requirements of 2.4.4 of this PART. The flexible hoses are to be so arranged that abrupt bends and twisting will not occur in the laying of the hoses and they are to be far away from vibration and hot sources.
4.7.2.7 Hydraulic remote control valves for essential service are to be capable of being operated with a hand pump in emergency condition, and indicators showing whether the valves are open or closed are to be provided at their operating positions.
4.7.2.8 The hydraulic transmission piping system for essential services is to be provided with a standby power pump which is to be capable of immediate use.

4.7.3 *Arrangement*

4.7.3.1 Hydraulic units with working pressure above 1.5 MPa are to be placed in separate spaces. If it is impracticable to locate such units in a separate space, adequate shielding is to be provided.

Section 8 THERMAL OIL SYSTEM

4.8.1 *General requirements*

4.8.1.1 The thermal oil used in the thermal oil system is to be compatible with the oil being heated.
4.8.1.2 Heating of liquid cargoes with flash points below 60℃ is to be arranged by means of a separate secondary system, located completely within the cargo area. However, a single circuit system may be accepted on the following conditions:
(1) System is so arranged that a positive pressure in the coil is to be at least 3 m water column above the static head of the cargo when circulating pump is not in operation.
(2) The thermal oil system expansion tank is to be fitted with high and low level alarms.
(3) Means are to be provided in the thermal oil system expansion tank for detection of flammable cargo vapors.
(4) Valves for the individual heating coils are to be provided with locking arrangement to ensure that the coils are under static pressure at all times.
4.8.1.3 For details of heaters in thermal oil systems, see the relevant requirements of Section 5, Chapter 6 of this PART.

4.8.2 *Plans and documents*

4.8.2.1 The piping and pumping system plans of thermal oil systems are to be submitted for approval.

4.8.3 *Design and manufacture*

4.8.3.1 The installation is generally to comprise at least two circulation pumps and two filters for the thermal oil.

4.8.3.2 In addition to the local operations, the inlet and outlet valves of oil-fired thermal oil heaters and exhaust-fired thermal oil heaters are to be shut off from a readily accessible position outside the compartment where they are situated. As an alternative, an arrangement for quick gravity drainage of the thermal oil contained in the system into a collecting tank is acceptable.

4.8.3.3 Arrangements are to be provided to permit from inside and from outside the heater spaces a quick discharge by gravity of the expansion tank into a suitable tank.

4.8.3.4 The monitoring and protection of thermal oil heaters are to comply with the relevant requirements of 6.5.5, Chapter 6 of this PART.

4.8.3.5 Tubes and pipes for thermal oil are to be seamless steel tubes or welded steel tubes and pipes.

4.8.3.6 Casings of pumps, valves and similar components are to be made of steel or equivalent ductile material. Copper and copper alloys are not to be used for those parts the surface of which is in direct contact with thermal oil so as to prevent oxidation of thermal oil.

4.8.3.7 Thermal oil piping is to have welded connections except that flanges may be used to the limited number necessary for inspection and maintenance. If necessary, suitable devices are to be provided for avoiding oil splash in case of leakage in way of the flanges. Marine steel recess type or plane flanges having a nominal pressure not less than 1.6 MPa are to be used for inlet and outlet pipe connection of thermal oil heaters. In the case of steel plane flanges, wire-reinforced graphite gaskets or expanded graphite composite gaskets are to be used.

Screw joints are not to be used for thermal oil piping.

4.8.3.8 The piping system is to be designed and constructed to permit expansion and contraction without abnormal stressing.

4.8.3.9 Particular attention is to be paid to the insulation of thermal oil piping and heater. Flanges are not permitted to be protected by the insulation material. Insulation material of thermal oil heater and piping is to be of an approved type and, as far as possible, it does not lower than the auto-ignition point of the thermal oil when impregnated by it.

4.8.3.10 The thermal oil system is also to comply with the requirements contained in the relevant Chapters of the Rules.

4.8.4 *Arrangement*

4.8.4.1 Where the thermal oil heaters are located in main and auxiliary machinery spaces, effective means are to be provided to prevent dispersal of thermal oil after leakage, such as coaming plate, etc.

4.8.4.2 The thermal oil circulating pumps are to be arranged for emergency stopping from a position outside the space where they are situated.

4.8.4.3 Drip trays are to be installed under the components of the installation where leakage is liable to occur. These drip trays are to be drained to an appropriate sludge tank.

4.8.4.4 The thermal oil system is to be fitted with an expansion tank of sufficient capacity. The thermal oil expansion tank and pumping plants are to be located in the same space as the thermal oil heaters.

4.8.4.5 Vents from expansion tanks and thermal oil storage tanks of the thermal oil heating plants are to be led to open deck.

4.8.4.6 Thermal oil piping and pumping system are to comply with the relevant requirements of Section 2 of this Chapter. Only one pump supplying thermal oil to the thermal oil expansion tank is acceptable.

4.8.4.7 Thermal oil pipes are not to pass through accommodation spaces nor control stations. Thermal oil piping passing through main and auxiliary machinery spaces is to be restricted as far as possible.

4.8.4.8 Thermal oil heater rooms are to be suitably mechanically ventilated and illuminated.

4.8.4.9 Thermal oil heater rooms are to be fitted with approved automatic fire detection system or fire alarm system.

4.8.5 *Additional requirements for exhaust-fired thermal oil heaters*

4.8.5.1 Exhaust-fired thermal oil heaters are also to comply with the relevant requirements of 6.5.4.5 and 6.5.4.6, Chapter 6 of this PART.

4.8.6 *Testing*

4.8.6.1 Thermal oil system and installation are to be subject to hydraulic and tightness tests according to the relevant requirements contained in Chapters 2 and 6 of this PART.
4.8.6.2 On completion, working tests of the thermal oil system are to be carried out in accordance with the test program.

Section 9 REQUIREMENTS CONCERNING USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS

4.9.1 *General requirements*

4.9.1.1 In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.
4.9.1.2 Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.
4.9.1.3 The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.
The whole surface of the boilers is to be gas-tight separated from the engine room. The boilers are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, is to be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils is to be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the provisions for tankers and with the outlet fitted with a suitable flameproof wire gauze of corrosion resistant material which is to be easily removable for cleaning.
4.9.1.4 Electric, internal combustion and steam (when the steam temperature is higher than 220°C) prime movers of driving pumps, of separators (if any) are to be fitted in the engine room or in another non-dangerous room.
Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted. The glands are to be efficiently lubricated from outside the pump room.
4.9.1.5 Pumps are to be fitted with a pressure relief by-pass from delivery to suction side and it is to be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.
4.9.1.6 When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

4.9.2 *Arrangement*

4.9.2.1 The piping for crude oil or slops and the draining pipes for the tray defined in 4.9.2.3 are to have a thickness as shown in Table 4.9.2.1.

External diameter and thickness of crude oil, slops and draining pipes (mm)

Table 4.9.2.1

External diameter d_e	Wall thickness t
$d_e \leq 82.5$	≥ 6.3
$88.9 < d_e \leq 108$	≥ 7.1
$114.3 < d_e \leq 139.7$	≥ 8.0
$152.4 \leq d_e$	≥ 8.8

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 1/5 of the vessel's beam (B) amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.
In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in 4.9.2.3. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flameproof wire gauze of

corrosion-resistant material which is to be easily removable for cleaning.
The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:
(1) injection of inert gas or steam in the duct in case of fire or leakage;
(2) purging of the duct before carrying out work on the piping in case of leakage.
4.9.2.2 In way of the bulkhead to which the duct defined in 4.9.2.1 is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves are to be interlocked with the hood exhaust fans (defined in 4.9.3.1) to ensure that whenever crude oil is circulating the fans are running.
4.9.2.3 Boilers are to be fitted with a tray or gutterway with a suitable height and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.
Such a tray or gutterway is to be fitted with a suitable flameproof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes are to pass through the tray or gutterway by means of a tight penetration and are then to be connected to the oil supply manifolds.
A quick closing master valve is to be fitted on the oil supply to each boiler manifold.
The tray or gutterway is to be fitted with a draining pipe discharging into a collecting tank in pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning. The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.

4.9.3 *Other requirements*

4.9.3.1 Boilers are to be fitted with suitable hood in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing on the other side, air inlet to burner register.
The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flameproof wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.
The exhaust fan prime movers are to be placed outside the duct and a gas-tight bulkhead penetration is to be arranged for the shaft.
Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type as required by ISC.
4.9.3.2 When using fuel oil for delivery to and return from boilers, fuel oil burning units are to be fitted in the boiler room. Fuel oil delivery to, and returns from, burners are to be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.
4.9.3.3 The boiler compartments are to be fitted with a mechanical ventilation plant and are to be designed in such a way as to avoid the formation of gas pockets.
Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants are to be separated from those for service of other compartments and are to be in accordance with relevant requirements of ISC.
4.9.3.4 A gas detector plant is to be fitted with intakes in the duct defined in 4.9.2.1 of this Section, in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.
4.9.3.5 Means are to be provided for the boiler to be automatically purged before firing.
4.9.3.6 Independent of the fire extinguishing plant as required in the Rules, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in 4.9.2.3 of this Section. The emission of extinguishing medium is automatically to stop the exhaust fan of the boiler hood.
4.9.3.7 A warning notice is to be fitted in an easily visible position near the boiler front. This notice is to specify that when an explosive mixture is signaled by the gas detector plant defined in 4.9.3.4, the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in 4.9.2.1 of this Section and turn the boilers to normal running on fuel oil.
4.9.3.8 One pilot burner in addition to the normal burning control is required.

Section 10 EXHAUST PIPELINES

4.10.1 *Arrangement*

4.10.1.1 Uptakes of boilers except exhaust gas boilers are not to be connected with exhaust pipelines of diesel engines.

4.10.1.2 Uptake governors or other means for closing the uptakes are not to be fitted within uptakes or funnels of oil-fired boilers.

4.10.2 *Silencers*

4.10.2.1 The structure of silencers is to be so designed that the internal cleaning and inspection can be carried out easily and these silencers are to be fitted with washing units with compressed air or steam or other cleaning appliances and drainage valves or cocks.

4.10.2.2 The external portion of silencers are to be packed with thermal insulation materials.

4.10.3 *Water heaters*

4.10.3.1 Water heaters fitted on the ducts for exhaust gas and smoke are, in general, to be of open type. If close type water heaters are fitted, the strength calculation is to be in accordance with the relevant requirements in Chapter 6 of this PART.

4.10.3.2 Close type water heaters are to be fitted with relief valves, pressure gauges, water level indicators, etc.

4.10.3.3 On construction, the close type water heaters are to be subject to a hydraulic test of 1.5 times the design pressure and the test pressure is not to be less than 0.4 MPa. The test of relief valves is to be carried out in accordance with the requirements in 6.3.5.3 of this PART.

4.10.3.4 Open type water heaters are to be fitted with a vent pipe of sufficient diameter and the vent pipe is not to be fitted with any closing appliances.

CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS

Section 1 GENERAL PROVISIONS

5.1.1 *Application*

5.1.1.1 The requirements of this Chapter apply to oil tankers having the main propelling machinery aft which are intended to carry crude oil and petroleum products having a flash point (closed cup test) not exceeding 60℃.

Where ships are intended for the carriage of cargo oil having a flash point (closed cup test) exceeding 60℃, the relevant requirements in Section 8 of this Chapter are to be complied with.

5.1.1.2 In addition to the requirements of this Chapter, piping systems for oil tankers are to comply with the relevant provisions contained in Chapters 2, 3 and 4 of this PART, where applicable.

5.1.2 *Arrangement of dangerous spaces*

5.1.2.1 Diesel engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within cargo tanks, pump rooms, cofferdams or other spaces liable to contain cargo oil or explosive vapors, or in spaces or zones immediately adjacent to cargo oil or slop tanks. The temperature of steam, or other fluid, in pipes (or heating coils) in these spaces is not to exceed 220℃.

5.1.3 *Steam connections to cargo tanks*

5.1.3.1 Where steaming out connections are provided for cargo tanks or cargo pipelines, they are to be fitted with valves of the screw-down non-return type. The main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the cargo tanks.

The steaming pipes are to be so arranged that the steam can be supplied to the upper and lower parts of the tank separately as necessary.

5.1.4 *Cargo pump room*

5.1.4.1 Cargo pump rooms are to be situated within, or adjacent to, the cargo tank area and are to be provided with ready means of access on open deck.

Pump rooms are to be totally independent of and to have no direct communication with machinery spaces.

5.1.4.2 In cargo pump rooms any drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

5.1.5 *Slop tanks*

5.1.5.1 In oil tankers, the venting arrangement, level sounding devices, heating systems and the piping for conveying oily water and cargo oil for the slop tanks designated for collecting and treating tank washings and dirty ballast from cargo tanks and other oily water are to comply with the relevant requirements for cargo tanks.

5.1.5.2 Discharge of oily water from slop tanks is to comply with the provisions for the prevention of pollution from ships.

5.1.6 *Gas freeing equipment*

5.1.6.1 Provision is to be made for the gas freeing of cargo tanks when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo tanks. For the purpose of monitoring flammable vapor, portable instruments are to be available on board for gas detection.

5.1.7 *Earthing of cargo oil pipes*

5.1.7.1 Earthing and bonding of cargo tanks and piping systems for the control of static electricity is to comply with the requirements in 1.3.4.11 of PART FOUR of the Rules.

5.1.8 *Prevention and free of spark*

5.1.8.1 The outlets of the exhaust gas pipes for main and auxiliary engines, boilers and other burner equipment are to be located at the sufficient height above the main deck. The horizontal distance of the outlets from cargo area is not to be less than 10 m. Where internal combustion engine is provided with approved spark arresters, as well as boilers and other burner equipment to be provided with spark arresters, their distance may be reduced to 5 m.

Section 2 CARGO HANDLING SYSTEM

5.2.1 *General requirements*

5.2.1.1 At least two independently power-driven cargo oil pumps are to be connected to the cargo oil system to pump cargo oil in each cargo tank. The arrangement is to ensure that the operation of other pumps is not affected if any one of the cargo oil pumps is inoperable.

5.2.1.2 If the cargo in cargo tank is lightered by a single deep well pump installed in each cargo tank, an emergency means for pumping out the tank is to be provided in case of failure of deep well pump.

5.2.2 *Cargo pumps*

5.2.2.1 Cargo pumps for the purpose of filling or emptying the cargo tanks are to be used exclusively for this purpose, except that they may be used for crude oil washing , cargo pump room drainage (see 5.3.2.1 of this Chapter) and filling or emptying water ballast in the cargo tanks. They are not to have any connections to compartments outside the range of cargo tanks.

5.2.2.2 Cargo pumps are to be installed in isolated pump rooms.

5.2.2.3 Where cargo pumps are driven by steam engines or turbines having a steam temperature not exceeding 220℃, the prime movers may be installed in the pump room.

5.2.2.4 Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump room plating. the glands are to be efficiently lubricated from outside pump room and are to be so designed as to prevent overheating. The seal parts of the glands are to be of materials that will not initiate sparks. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 0.34 MPa before fitting.

5.2.2.5 Cargo pumps installed in cargo pump rooms and driven by shafts passing through pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands and shaft bearings of cargo pumps from outside of pump room. Alarm is to be initiated for excessive temperature of the above-mentioned glands and bearings.

5.2.2.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump, and to effectively limit the pump discharge pressure to the design pressure of the system.

5.2.2.7 Cargo oil pumps are to be capable of being stopped from a suitable position outside the pump room, as well as at the pumps.

5.2.2.8 A pressure gauge indicating the discharge pressure is to be fitted at the delivery side of each cargo oil pump. An additional gauge is to be fitted in the vicinity of the pump control station.

5.2.2.9 The safety requirements for stripping pumps fitted onboard and their piping systems are to be the same as those to cargo oil pumps and their piping systems.

5.2.2.10 Any integral hydraulic and/or electrical system used to drive both cargo and ballast pumps (integral cargo and ballast system) is to comply with the relevant provisions in 2.6.7, Chapter 2, PART FOUR of the Rules.

5.2.3 *Cargo piping system*

5.2.3.1 Cargo oil pipes are to be laid only within the cargo tank area, except for the bow or stern loading and unloading equipment outside cargo tank specified in the following 5.2.3.12.

5.2.3.2 Unless stated otherwise, cargo oil pipes are to be fully independent of other pipes.

5.2.3.3 Where Cargo tanks and slop tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tanks, so as to minimize the generation of static electricity.

5.2.3.4 Where it is necessary to fill the oil tanks by using the cargo oil suction pipes, a by-pass is to be provided to connect the suction and discharge ends of cargo oil pump. A stop valve is to be fitted on the by-pass.

5.2.3.5 Where the cargo oil piping system is used also as a ballast system for the cargo tanks, a blank flange or a removable spool piece is to be fitted between the sea chest valve and the cargo oil main, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.

The discharge of oily ballast water is to comply with the requirements for the prevention of pollution from ships.

5.2.3.6 Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected, are to be of steel or ductile material. They are to be of robust construction and strongly supported.

A manually operated shut-off valve is to be fitted to each shore loading/discharging connection.

5.2.3.7 Expansion joints or bends are to be provided, where necessary, in the cargo pipelines.

5.2.3.8 For cargo piping system, means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or slop tank or to the shore facilities.

5.2.3.9 The operating rods for cargo valves in cargo tanks are to be extended to positions above the open deck. In the case of cargo tanks which are located adjacent to below-deck pump rooms or pipe tunnels, the operating rods may be located in these spaces at the bulkhead.

Stuffing boxes are to be fitted where the operating rod passes through the deck or bulkhead and to be so constructed that packing may be renewed from outside the cargo tanks. Indicators are to be provided at the operating hand wheels to show whether the valves are open or closed.

5.2.3.10 Materials used for the friction parts of the valves and operating rods of the cargo oil piping and of flexible couplings in shafts between the cargo pumps and the prime movers are to be such as to preclude the possibility of sparking while in operation.

5.2.3.11 Cargo oil pipelines are not to pass through ballast tanks. Where this can not be avoided, the pipes passing through ballast tanks are to have a wall thickness in accordance with the requirements in Table 5.3.4.2 of this Chapter and are to be provided with welded joints.

5.2.3.12 Bow or stern loading and unloading

Where bow or stern loading and unloading connections are provided outside cargo tank area, the arrangements are to be as follows:

(1) Cargo lines for bow or stern loading and unloading are to be installed outside accommodation spaces, service spaces, machinery spaces and control stations, and are to be clearly identified.

(2) Pipe joints outside the cargo area and used for bow or stern loading and unloading are to be welded.

(3) A spectacle flange or a removable spool piece is to be fitted at the connection line between the cargo loading and unloading line and cargo main line in cargo area, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.

(4) The loading and unloading connection is to be fitted with a shut-off valve and a blank flange. Spill containment is to be provided under the loading and unloading manifold.

(5) Arrangements are to be provided for cargo lines outside of the cargo area for easy draining to a slop tank or cargo tank.

(6) Space within 3 m from the oil spill containment boundary and connection mentioned in (4) above is considered to be gas hazardous area and is to be clearly identified.

(7) Fixed deck foam fire-extinguishing system required for cargo area is to effectively protect bow or stern loading and unloading area.

5.2.4 *Remote control valves*

5.2.4.1 Valves on deck and in pump rooms which are provided with remote control are to have local manual operating devices independent of the remote operating mechanism or emergency means for operating the valve actuators in the event of damage to the main hydraulic circuits on deck, such as connections, with isolating valves, fitted to the pipes near the valve actuators as far as possible for coupling to a standby portable pump carried on board.

5.2.4.2 Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank, or alternative means of emptying the tanks in the event of a defective actuator, are to be provided.

It is recommended that the lines to the valve actuators be led vertically inside the tanks from deck, and that connections, with isolating valves, be provided on deck lines for coupling to a standby portable pump carried on board for emergency operation of the valves in the event of damage to the main hydraulic circuits on deck.

5.2.4.3 Indication is to be provided at the remote control stations showing whether the valve is open or shut.

5.2.4.4 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. The design of the actuators is to be such that contamination of the operating medium with cargo oil cannot take place under normal operating conditions.

5.2.4.5 Compressed air is not to be used for operating actuators inside cargo tanks.

5.2.4.6 For the actuators in cargo tank, the supply tank is to be located as high as practicable above the level of the top of cargo tank, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with high and low level audible and visual alarms.

Section 3 BILGE, BALLAST AND OTHER PIPING SYSTEMS

5.3.1 *Pumping arrangements at ends of ship outside ranges of cargo tanks*

5.3.1.1 The pumping arrangements in machinery spaces and the forward end of the ship are to comply with the requirements for general cargo ships, unless otherwise specified in this Section.

5.3.1.2 The internal diameter d_1 of the bilge main and direct bilge suction in machinery spaces is to be calculated according to the requirements of 3.4.3.1 of this PART. L in the formula may be the ship's length reduced by the combined length of the cargo area. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines.

5.3.1.3 The internal diameter d_2 of branch bilge suction pipes of machinery spaces is to be in accordance with the requirements in 3.4.3.3 of this PART.

5.3.1.4 Bilge, ballast and oil fuel lines, which are connected to pumps, tanks or compartments at the ends of the ship, are not to pass through cargo tanks or have any connections to cargo tanks or cargo lines, in general, no objection will be made to these lines being led through ballast tanks or void spaces within the range of the cargo tanks.

5.3.1.5 The arrangement of all pumps serving tanks directly adjacent to cargo tanks is also to comply with the requirements to cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter, except for pumps and pipes serving fuel oil tanks located behind cargo tanks and directly adjacent to cargo tanks. Pumps and pipings serving above-mentioned fuel oil tanks may be located in engine room.

5.3.1.6 Unless specified otherwise, the piping system outside cargo area is to be mutual independent from the piping system within cargo area.

5.3.2 *Cargo pump room drainage*

5.3.2.1 Provision is to be made for the drainage of the cargo pump rooms by pump or bilge ejector suctions. Where cargo pumps or cargo stripping pumps are used for this purpose, the bilge suctions are to be fitted with screw-down non-return valves and, in addition, a stop valve is to be fitted on the pump connection to the bilge valve chest.

5.3.2.2 Cargo pump room suctions are not to enter machinery spaces.

5.3.2.3 The bilge drainage of the cargo pump rooms is to comply with the relevant requirements for the prevention of pollution from ships. It is recommended that cargo pump room bilge is to be drained into the slop tanks.

5.3.2.4 All the cargo pump rooms are to be provided with bilge level monitoring devices and suitable synchronous alarm devices.

5.3.3 *Cofferdam drainage within the ranges of cargo tanks*

5.3.3.1 The bilge suction equipment of cofferdam is to be installed within the ranges of cargo tanks. The requirements of 5.3.2.1 of this Section are to be complied with, where cargo pumps or cargo stripping pumps are used for drainage. Alternatively, cofferdams may be drained by bilge ejectors.

5.3.4 *Ballast piping within the range of the cargo tanks*

5.3.4.1 Ballast tanks within the range of cargo tanks and ballast pipelines in the double bottom tank are to be provided with separate ballast pumps and pipelines. The ballast pump is to be located in the cargo pump room or other suitable space within the range of the cargo tanks. The arrangement of ballast pumps is also to comply with the requirements for cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter. However, If ballast pump is located in individual ballast pump tank, the requirements of 5.2.2.5 may be exempted.

5.3.4.2 The ballast lines are not to pass through cargo tanks. Where this cannot be avoided, the ballast lines passing through cargo tanks are to be heavy gauge steel, having welded or heavy flanged joints. The pipes in cargo tanks are not to be less than the value given in Table 5.3.4.2 in thickness. The number of joints is to be kept to a minimum. Where it is proposed to use material which is more resistant to corrosion than carbon steel, the pipe thickness may be suitably reduced.

Pipe thickness inside cargo tanks *Table 5.3.4.2*

Nominal diameter of pipe① (mm)	Minimum wall thickness (mm)
50	6.3
100	8.6
125	9.5
150	11.0
200 and above	12.5

Note: ① For nominal diameter with the value between those listed in the Table, the corresponding pipe thickness may be

calculated by insertion.

5.3.4.3 Expansion bends or bellows, not glands, are to be fitted to the ballast pipes in the cargo tanks.

5.3.4.4 For clean ballast piping, provision may be made for emergency discharge of water ballast by means of a portable spool connection to cargo oil pump and where this is arranged, a screw-down non-return valve is to be fitted in the ballast suction to the cargo oil pump and a screw-down valve is to be fitted to the cargo oil lines.

5.3.4.5 Where the clean ballast pumps are installed in a cargo pump room, the sea inlets of these pumps are to be entirely separated from the sea inlets of the cargo pumps.

5.3.4.6 Water supply of fire main may be used as dynamic water of eductors for discharging ballast water of ballast tank or for discharging bilge water of cofferdam in cargo area, and the following requirements are to be complied with:

(1) eductors are to be located in cargo area such as pump tank;

(2) water supply pipes from fire main for the above-mentioned purpose are to be led from upper deck in cargo hold area;

(3) a stop-check valve is to be fitted at appropriate position near deck before the water supply pipe passes through deck.

5.3.5 *Air and sounding pipes for cofferdams*

5.3.5.1 Deep cofferdams at the fore and aft ends of the cargo spaces and other tanks or cofferdams within the range of the cargo tanks, which are not intended for cargo, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with renewable wire gauze diaphragms at their outlets. The height of air pipes from the deck to the point where water may have access below is not to be less than 760 mm.

5.3.5.2 So far as practicable, the air and sounding pipes required in 5.3.5.1 are not to pass through cargo tanks. Were side ballast tank or empty side tank are not provided on ship, the air and sounding pipes in way of the double bottom may pass through cargo tanks. But a wall thickness of the pipes passing through cargo tanks are to comply with the requirements in Table 5.3.4.2 of this Chapter and the pipes are to be completion or with welded joints.

5.3.6 *Location and separation of spaces in combination carriers*

5.3.6.1 The slop tanks are to be surrounded by cofferdams except where the boundaries of the slop tanks where slop may be carried on dry cargo voyages are the hull, main cargo deck, cargo pump-room bulkhead or fuel oil tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump-room or other enclosed space. Means are to be provided for filling the cofferdams with water and for draining them.

5.3.6.2 Means are to be provided for isolating the piping connecting the pump-room with the slop tanks referred to in 5.3.6.1. The means of isolation are to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump-room directly after the piping penetrates the bulkhead. A separate pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly over the open deck when the ship is in the dry cargo mode.

5.3.6.3 Hatches and tank cleaning openings to slop tanks are only permitted on the open deck and are to be fitted with closing arrangements. Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

5.3.6.4 Where cargo wing tanks are provided, cargo oil lines below deck are to be installed inside these tanks. Where cargo wing tanks are not provided, cargo oil lines below deck are to be placed in special ducts which are capable of being adequately cleaned and ventilated.

Section 4 CARGO OIL HEATING

5.4.1 *General requirements*

5.4.1.1 The medium used for heating cargo oil is to have a temperature not exceeding 220℃.

5.4.2 *Steam heating*

5.4.2.1 The steam used for heating cargo oil is to be of saturated steam.

5.4.2.2 An observation tank is to be provided for the heating coil drains and is to be located in a well ventilated and well illuminated part of the machinery space remote from the boilers, diesel engine exhaust

pipes and electrical equipment. The upper drain pipe of the tank is to be led to a sludge tank.
5.4.2.3 The heating steam supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and these lines are to be run above the weather deck.
5.4.2.4 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank. The heating coil exhaust pipes of the cargo oil heating systems for each tank are to be fitted with inspection valves or cocks on the open deck to check the heating coils for leakage.
5.4.2.5 Spectacle flanges or spool pipes are to be provided in the heating steam supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

5.4.3 *Thermal oil heating*
5.4.3.1 Thermal oil heating of cargo oil is to comply with the relevant requirements of Section 8, Chapter 4 of this PART.
5.4.3.2 The heating oil supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank.
5.4.3.3 Isolating shut-off valves are to be provided at the inlet and outlet connections to the heating oil circuit(s) of each tank.
5.4.3.4 Spectacle flanges or spool pipes are to be provided in the heating oil supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks.

Section 5 CARGO TANK LEVEL SOUNDING

5.5.1 *General requirements*
5.5.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level, and the requirements respectively in 5.5.2 to 5.5.4 below are to be complied with.

5.5.2 *Closed sounding devices*
5.5.2.1 In oil tankers fitted with a fixed inert gas system, the cargo tanks are to be fitted with closed sounding devices which do not permit the escape of cargo to the atmosphere when being used.

5.5.3 *Limited sounding devices*
5.5.3.1 Sounding pipes or other approved devices, which may permit a limited amount of vapor to escape to atmosphere when being used, would be accepted for those tanks which are not required to be fitted with closed sounding devices. The devices are to be so designed as to minimize the sudden release of vapor or liquid under pressure and the possibility of liquid spillage on deck. Means are also to be provided for relieving tank pressure before the device is operated.
Arrangements which permit the escape of vapor to the atmosphere are not to be fitted in enclosed spaces.

5.5.4 *Open sounding devices*
5.5.4.1 Separate ullage openings may be fitted as a reserve means for sounding cargo tanks.

Section 6 CARGO TANK VENTING ARRANGEMENTS

5.6.1 *General requirements*
5.6.1.1 Each cargo tank is to be fitted with venting arrangements which will limit the pressure or vacuum in the tanks. Vent pipes of cargo tanks are not to be in connection with the air pipes led from other tanks. Cargo tank venting arrangements are to be designed to provide:
(1) venting of large volumes of vapor/air mixtures during cargo handling and gas freeing operation;
(2) pressure/vacuum release of small volumes of vapor/air mixtures flowing during a normal voyage due to the change of temperature;
(3) a secondary means of allowing full flow relief of vapors, air or inert gas mixtures is to be provided in the event of failure of the arrangements in (1). The secondary means are to be capable of preventing over-pressure or under-pressure in the event of damage to, or inadvertent closing of, the means of isolation

required in the paragraph 5.6.2.2 of the Section. Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in 5.6.1.1 (1), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

5.6.2 *Pressure/vacuum and venting systems*

5.6.2.1 The pressure/vacuum system and venting system may be separate or combined and may be connected to an inert gas system.

5.6.2.2 The vent and/or pressure/vacuum valve stand pipes are to be connected to the highest part of each tank, and where combined systems are adopted, a means of isolation is to be provided between each tank and a common main. Any means of isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with the provisions of 5.6.1.1(2). If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group are to be fitted with a means for over-pressure or under-pressure protection as required in 5.6.1.1(3) of this Section. Any isolation is also to continue to permit the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

5.6.2.3 In no case are shut-off valves to be fitted either above or in the pipe leading to a pressure/vacuum valves. However, by-pass valves may be fitted or provision may be made to enable the tank pressure/vacuum valves to be held in an open position. The arrangements are to be such that clear indication is given when the by-pass valve is open or the pressure/vacuum valve is secured in the open position.

5.6.2.4 The pressure/vacuum valve is to be located on open deck and means are to be provided to enable the functioning of the valve to be easily checked.

5.6.2.5 Pressure/vacuum valves are to be capable of preventing the cargo tanks from sustaining a positive pressure (generally not more than 0.021 MPa) which is greater than the testing pressure, and a negative pressure of less than 0.007 MPa.

5.6.2.6 The area of the venting system used during cargo loading is to be based on the maximum design loading rate and a gas evolution factor of 1.25.

5.6.2.7 Suitable drainage arrangements are to be provided in the vapor lines where condensate might collect.

5.6.3 *Arrangement of vapor outlets*

5.6.3.1 Outlets from vent pipes and, where necessary, outlets/inlets from pressure/vacuum valves are to be provided with readily renewable wire gauze①. Material of wire gauze is to be resistant to corrosion.

5.6.3.2 Vent outlets and pressure/vacuum valve, if used during loading, are to be arranged to discharge the vapor in an upward vertical direction. Vent outlets and pressure/vacuum valve inlets and outlets are to be arranged to prevent the entrance of water into the cargo tanks.

5.6.4 *Height and location of cargo tank vent outlets*

5.6.4.1 Vent outlets for cargo loading, discharging and ballasting required in 5.6.1.1(1) of this Section are to:

(1) permit the free flow of vapor mixtures; or

(2) permit the throttling of the discharge of the vapor mixtures to achieve a velocity of not less than 30 m/s. They are also to be so arranged that the vapor mixture is discharged vertically upwards.

Where the method is by free flow of vapor mixtures, the arrangement is to be such that the outlet is not to be less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

Where the method is by high-velocity discharge, the outlets are to be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

---

① Refer to MSC/Circ.677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers and MSC/Circ.450/Rev.1 – Revised Factors to be Taken into Consideration when Designing Cargo Tank Venting and Gas Freeing Arrangements.

5.6.4.2 Openings for pressure release required in 5.6.1.1(2) of this Section are to be arranged in accordance with 5.6.4.1 of this Section.

5.6.5 *Preventive measures against liquid rising in the venting system*

5.6.5.1 Provisions are to be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This may be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and cargo tank filling procedures. For the purposes of this regulation, spill valves are not considered equivalent to an overflow system.

Section 7 REQUIREMENTS FOR DOUBLE HULL SPACES OF OIL TANKERS

5.7.1 *Inerting, ventilation and gas measurement of double hull spaces*

5.7.1.1 Double hull spaces are to be provided with suitable ventilation connections.

5.7.1.2 On tankers required to be fitted with inert gas systems:

(1) double hull spaces are to be fitted with suitable connections for the supply of inert gas;

(2) where such spaces are connected to an inert gas distribution system, means is to be provided to prevent flammable gases from the cargo tanks entering the double hull spaces through the system;

(3) where such are not connected to an inert gas distribution system, appropriate means is to be provided to allow connection to the inert gas main.

5.7.1.3 Tankers are to be provided with suitable portable instruments for measuring oxygen and flammable vapor concentrations. In selecting these instruments, due attention is to be given for their use in combination with the gas sampling systems referred to in 5.7.1.4 of this Section.

5.7.1.4 Where atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems is to be adapted to the design of such spaces.

5.7.1.5 The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastic materials are used, they are to be electrically conductive.

Section 8 REQUIREMENTS FOR OIL TANKERS INTENDED FOR CARRIAGE OF CARGO OIL HAVING A FLASH POINT EXCEEDING 60℃

5.8.1 *General requirements*

5.8.1.1 For oil tankers intended for the carriage of cargo oil having a flash point above 60℃ (closed cup test) and where the maximum temperature heated for the cargo oil in cargo oil tanks is at least 10℃ below the flash point of the cargo oil, the requirements of this Chapter are to be complied with, but the following in this Chapter may not be applicable:

5.1.2, 5.1.4, 5.1.6, 5.1.8, 5.2.2.1 to 5.2.2.5, 5.2.3.1, 5.2.3.12, 5.2.4.5, 5.3.1.5, 5.3.3.1, 5.3.4.1, 5.3.4.6, 5.5.2.1, 5.6.1 to 5.6.5 and 5.7.1.

5.8.2 *Vent pipes of cargo tanks*

5.8.2.1 Vent pipes are to be led from the highest part of the tank to the open area above the freeboard deck and such pipes are not to be connected to those of other than cargo oil tank spaces.

5.8.2.2 Vent pipes required in 5.8.2.1 of this Section may be fitted for each cargo oil tank, vent pipes required for several cargo oil tanks may also be led to a common main, but it is proposed that a pressure/vacuum valves is to be fitted on the common main.

5.8.2.3 The height of the outlet ends of vent pipes (including branch and main) are not to be less than 760 mm above the freeboard deck.

5.8.2.4 The outlet ends of vent pipes are to be provided with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.

CHAPTER 6 BOILERS AND PRESSURE VESSELS

Section 1 GENERAL PROVISIONS

6.1.1 *General requirements*

6.1.1.1 The requirements of this Chapter apply to the following devices or equipment of welded construction:

(1) boilers generating steam with a pressure above atmospheric pressure (0.103 MPa) or heating pressurized hot water above 120℃;

(2) thermal oil heaters;

(3) pressure vessels.

6.1.1.2 The certification requirements and product survey of boilers and pressure vessels are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.

6.1.2 *Classification*

6.1.2.1 For the purpose of the Rules, boilers and pressure vessels are classified in accordance with the design pressure p (MPa), thickness δ (mm) of cylindrical shell, working temperature t (℃) of cylindrical shell and inner diameter d (mm) of pressure vessel, see Table 6.1.2.1.

Classes of Boilers and Pressure Vessels *Table 6.1.2.1*

Type \ Class	Class I	Class II	Class III
Boilers or thermal oil heaters	$p > 0.35$	$p \leq 0.35$	–
Steam generators	$p > 1.15$, or $p.d > 1500$	Steam generators other than Class I	–
Pressure vessels or heat exchangers	$p > 4$, or $\delta > 40$, or $t > 350$	$4 \geq p > 1.57$, or $40 \geq \delta > 16$, or $350 \geq t > 150$	Pressure vessels and heat exchangers other than Classes I and II
Pressure vessels or heat exchangers for liquefied gases, toxic and corrosive substances	All	–	–

6.1.2.2 The small auxiliary boilers mentioned in this Chapter are the boilers having an evaporating capacity not exceeding 1,000 kg per hour and a design pressure not exceeding 0.78 MPa.

6.1.3 *Definitions*

6.1.3.1 For the purpose of this Chapter:

(1) Design pressure

The design pressure is the maximum permissible working pressure for boilers and pressure vessels. Strength calculations for boilers and pressure vessels are to be based on the design pressure and not to be less than the highest set pressure of safety valve.

The design pressure of economizers is the maximum working pressure of the medium in the economizer.

(2) Metal temperature

The metal temperature is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated in the relevant plans of design.

(3) Boilers

Boilers include all closed vessels together with their fittings which receive the thermal energy released by burning fuel or any other thermal energy for the generation of steam or hot water.

(4) Pressure vessels

Pressure vessels are vessels together with their fittings which are subjected to an external or internal pressure.

(5) Heat exchangers

Heat exchangers are devices together with their fittings which are used for heat exchange between two or more media. Heat exchangers and their fittings are to be designed, manufactured and inspected in accordance with the requirements for pressure vessels.

(6) Steam generators

Steam generators are heat exchangers together with their fittings which are used to generate steam. Unless stated otherwise, the requirements for boilers in this Chapter apply to steam generators.

(7) Thermal oil heaters

Thermal oil heaters are devices in which thermal oil is heated and circulated.

6.1.4 *Plans and documents*

6.1.4.1 The following plans and documents of boilers are to be submitted for approval:
(1) General arrangement (the highest part of heating surfaces of the boiler is to be clearly indicated in the submitted drawing);
(2) Body construction (including details of welded connections, attachments and supports);
(3) Construction of pressure parts (cylindrical shell, steam and water drums, headers, combustion chamber, furnace, superheater, desuperheater, economizer, etc.);
(4) Arrangement of mountings and fittings;
(5) Safety valves with diameter calculation;
(6) Strength calculations;
(7) Heat treatment procedures of welded connections;
(8) Test pressure.

6.1.4.2 The following plans and documents of pressure vessels are to be submitted for approval:
(1) General arrangement;
(2) Body construction (including details of welded connections, attachments and supports);
(3) Construction of pressure parts (cylindrical shell, end plate, etc.);
(4) Arrangement of mountings and fittings;
(5) Strength calculations;
(6) Test pressure.

6.1.4.3 For thermal oil heaters, the following plans and information are to be submitted for approval or reference, in addition to those as required for boilers:
(1) Plan of monitoring and alarm system;
(2) Plan of fire-extinguishing system and relevant calculations (if applicable);
(3) Design temperature and pressure of the system, physical and chemical properties (e.g. viscosity, flash point, ignition temperature, decomposition temperature, self-ignition temperature) of thermal oil (for reference);
(4) Operation and maintenance instructions (for reference).

Section 2 DESIGN AND MANUFACTURE

6.2.1 *Design*

6.2.1.1 The design of boilers and pressure vessels is to comply with the relevant requirements in Appendix 1 to Appendix 6 of this Chapter. All the designs are to be submitted for approval prior to construction.

6.2.1.2 The metal temperature of boiler parts is, in any case, not to be less than the value given in Table 6.2.1.2, nor less than 250℃. The metal temperature of the pressure vessel parts in direct contact with hot medium is to be taken as the highest working temperature of the medium.

Metal temperature of boiler parts *Table 6.2.1.2*

Components \ Working condition	Not heated	Heated but well insulated	Subject to convective heat	Subject to radiant heat
Steam or water drum, header	t	t + 10℃	t + 50℃	–
Superheater cylinder or header	t + 15℃	t + 30℃	t + 50℃	–
Boiler generating tube	–	–	t + 25℃	t + 50℃
Superheater pipe	–	–	t + 35℃	t + 50℃
Economizer pipe	–	–	t + 30℃	–
Furnace, smoke duct and back tube sheet in dry back combustion chamber	–	–	–	t + 90℃
Wet back combustion chamber	–	–	–	t + 50℃

Note: t — working medium temperature, (℃).

6.2.1.3 Boilers are to be adequately insulated. The insulation is to have a metallic sheathing. When the boiler is under working conditions, the temperature of the sheathing is generally not to exceed 60℃.

6.2.1.4 Every shell type economizer is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

6.2.2 *Materials*

6.2.2.1 The materials used in the construction of boilers and pressure vessels are to be in compliance with the relevant provisions contained in ISC Rules for Materials and Welding. Where it is proposed to use materials other than those specified in the aforesaid, details of the mechanical properties (including mechanical property values used for the calculation of allowable stresses), chemical compositions and heat treatment are to be submitted for approval.

6.2.3 *Plate cutting*

6.2.3.1 Plates are to be cut to size and shaped by machine flame cutting and/or machining. Where the plate thickness does not exceed 25 mm, cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of 1/4 of the plate thickness, but in no case by less than 3 mm. After being cut and before further work is carried out upon them, all plate edges are to be examined for laminations and cracks.

6.2.4 *Forming*

6.2.4.1 Plates for shell sections and end plates are, so far as possible, to be hot and cold formed by machine. Forming by hammering is not to be employed. Forming is not to impair the quality of the material regardless of heating or not.

6.2.4.2 After forming, both shell plates and end plates are to be suitably heat treated. This heat treatment may be held concurrently with post-weld heat treatment.

6.2.5 *Allowable stress*

6.2.5.1 The allowable stress of boiler and pressure vessel parts is to be determined by the following formulae, and the lower value is to be taken:

(1) Metal temperature equal to or less than 50℃:

$[\sigma] = R_m/2.7$; $[\sigma] = R_{eH}/1.5$

(2) Metal temperature more than 50℃:

$[\sigma] = R_m/2.7$; $[\sigma] = R^T_{eH}/1.5$; $[\sigma] = R^T_{m100000}/1.5$

(3) Pressure vessels for stowage of liquid gas:

$[\sigma] = R_m/3.0$; $[\sigma] = R_{eH}/2.0$

where: R_m — specified tensile strength of material at room temperature, in N/mm^2;

R_{eH} — specified yield stress of material at room temperature, in N/mm^2;

R^T_{eH} — specified yield stress or proof stress of material at metal temperature, in N/mm^2;

$R^T_{m100000}$ — average stress to produce rupture in 10^5 h of material at metal temperature, in N/mm^2. In general, it is to be selected according to the relevant requirements of ISC Rules for Materials and Welding when the metal temperature is more than 350℃.

The allowable stress for steel castings is to be taken as 80% of the value determined by the method indicated above, using the appropriate value for cast steel.

6.2.6 *Joint factor of welded seam*

6.2.6.1 For welded seams welded on both side or on one side with a sealing run, the strength factor φ' used in the equations in this Chapter is given in Table 6.2.6.1 based on the method of examination employed.

Strength factor φ' of welded seam **Table 6.2.6.1**

Class	Strength factor of welded seam	Perspective inspection	Conventional welded seam test plate	Heat treatment
I	1	To be done, see Rules for Materials and Welding	To be done	See Rules for Materials and Welding
II	0.85	To be done, see Rules for Materials and Welding	To be done	See Rules for Materials and Welding
III	0.60	–	–	–

6.2.6.2 For boilers of Class II and pressure vessels of Classes II and III where higher joint factor of welded seam than that required for the respective class is selected, the welded seams are to be examined in accordance with the requirements for the higher joint factor of welded seam.

6.2.7 *Welding and heat treatment*

6.2.7.1 The welding, welds examination and post-welding heat treatment of all pressure parts of boilers and pressure vessels are to comply with the requirements of ISC Rules for Materials and Welding.

6.2.7.2 Cold-formed cylindrical shells of boilers and pressure vessels are to be subject to stress relief heat treatment, which may be carried out together with the post-welding heat treatment. For cylindrical shell having an inner diameter greater than or equal to 20 times the thickness of shell plate, the heat treatment may be dispensed with.

6.2.7.3 Hot formed parts of boilers or pressure vessels are to be normalized provided that hot forming is not carried out at a temperature within the normalizing range. Parts made of alloy steel are, in addition, to be tempered as necessary.

6.2.8 *Pads*

6.2.8.1 The pads for securing the mountings and fittings to boilers and pressure vessels are to be of sufficient thickness to permit the studs being screwed into them with a length not less than the diameter of the studs without penetrating the pads. The pads and cylindrical shell are to be tightly fitted.

6.2.9 *Access arrangements*

6.2.9.1 Boilers and pressure vessels are to be provided with manholes to facilitate internal examination and cleaning of the cylindrical shell and steam or water drums. In the case of boiler components and pressure vessels such as cylindrical shells, headers, which are too small to permit entry, sufficient number of sight holes for these purposes is to be provided.

Manholes in cylindrical shells are preferably to have their minor axes arranged longitudinally.

6.2.9.2 Doors for manholes and sight holes are to be made of steel plate or steel forgings. Doors of the internal type are to be provided with spigots which have a clearance of not more than 2 mm all round.

6.2.9.3 Holes of boilers and pressure vessels are in general to comply with the following:

(1) Boilers with an inside diameter of more than 1000 mm and vessels with an inside diameter of more than 800 mm are to be equipped at least with one manhole.

(2) In the case of boilers and their components (e.g. cylindrical shells, headers) which are too small to permit entry for internal examination and cleaning, and of pressure vessels on which no manhole is practicable, sufficient head holes or hand holes for these purposes are to be provided.

(3) Vessels with an inside diameter of up to 300 mm are not necessarily to be equipped with any inspection hole.

(4) The minimum dimensions of various holes are in general required as follows:

manholes: 300 × 400 mm (minimum diameter of 400 mm for circular ones);
head holes: 220 × 320 mm (minimum diameter of 320 mm for circular ones);
hand holes: 80 × 100 mm.

6.2.10 *Structure attachment*

6.2.10.1 Where cylindrical shell consists of shell plates and/or tube plates which differ in thickness, the shell plates and/or tube plates are to be so butt welded that their centerlines form a continuous circle (see Figure 6.2.10.1). At the welded joint, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than two times the difference in the thickness.

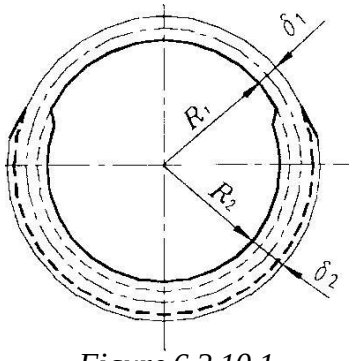


Figure 6.2.10.1

6.2.10.2 For the attachment of torispherical or ellipsoidal ends to cylindrical shells, see Figure 6.2.10.2. Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the

two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

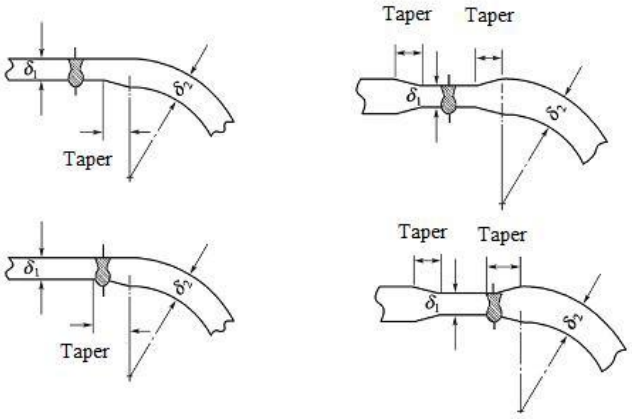


Figure 6.2.10.2

The thickness of the plates at the position of the circumferential weld is not to be less than that required for cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material.

6.2.10.3 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be tapered to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, see Figure 6.2.10.3.

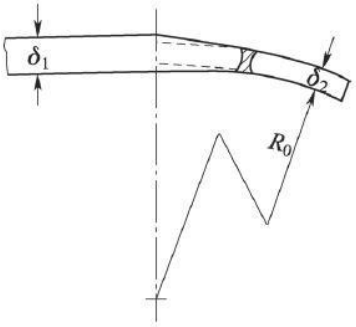
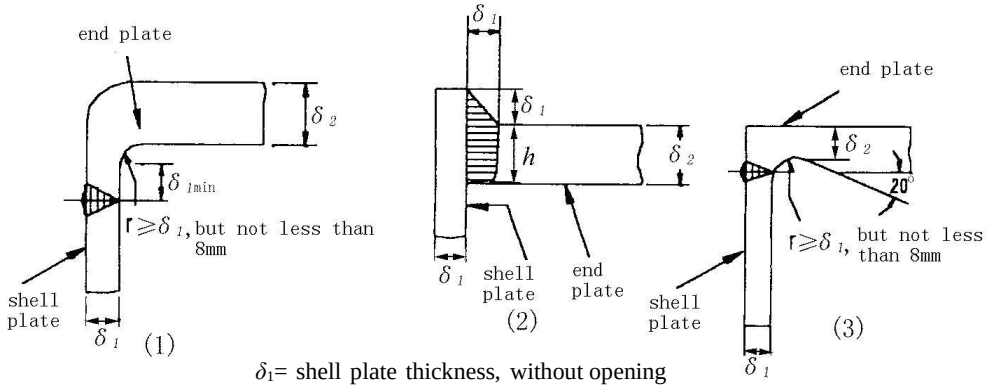


Figure 6.2.10.3

If the hemispherical end is provided with a parallel portion to be butt welded to the shell, the thickness of this portion is not to be less than that required for a seamless or welded shell.

6.2.10.4 The typical acceptable methods of attaching flat ends to cylindrical and rectangular headers are as shown in Figure 6.2.10.4.



δ_1= shell plate thickness, without opening weakening

δ_2= end plate thickness

$h = 2\delta_1$ or δ_2 -1.5mm, whichever is lesser

Figure 6.2.10.4

6.2.11 Fitting of tubes in water tube boilers

6.2.11.1 Where boiler tubes are expanded into the tube holes and are not normal to the tube plates, there is to be a neck having an effective depth h of not less than 13 mm (see Figure 6.2.11.1). Where the tubes are practically normal to their plates, this parallel seating is not to be less than 9.5 mm in depth.

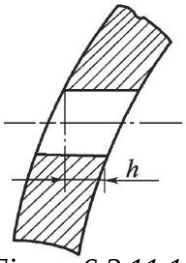


Figure 6.2.11.1

6.2.11.2 For tubes expanded into the tube holes in cylindrical shell or headers, they are to project through the neck or belt of parallel seating by at least 6 mm, but not more than 16 mm. Where the tube ends are secured from drawing out by means of bell mouthing, the included angle of belling is not to be less than 30°.

6.2.12 *Design and construction of exhaust heating shell type economizers*

6.2.12.1 Design and construction of shell type economizers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

6.2.13 *Prevention of soot accumulation*

6.2.13.1 Where the design (e.g. using boiler tubes with extended heat exchange surface) of exhaust gas boilers and economizers may lead to soot accumulation, resulting in fires or risks of excessive flow resistance, effective measures are to be taken to control soot accumulation, e.g. by fitting effective soot cleaning system, exhaust gas bypass, etc.

6.2.13.2 Unless specified otherwise by the flag States, the washing water generated during operation of the soot cleaning system is to be drained to appropriate tanks, and necessary measures are to be taken to prevent water from flowing into diesel engines.

Section 3 BOILER MOUNTINGS AND FITTINGS

6.3.1 *General requirements*

6.3.1.1 Boiler mountings are to be connected to pads or stand-pipes with flanges. Mountings under 20 mm in diameter may be fitted with screws on pads or stand-pipes.

Valves over 30 mm in diameter and the covers are to be secured by flange connections and valves having a diameter up to 30 mm and the covers may be secured by screw connections with stoppers.

6.3.1.2 Valve bodies for boilers are to be made of steel or other equivalent material. For boilers having a design pressure not exceeding 0.98 MPa and steam temperature not exceeding 220℃, the valve bodies may be made of cast iron with the exception of blow-off valves.

6.3.1.3 Boiler mountings are to be located in positions easily accessible for maintenance and operation.

6.3.2 *Feed check valves*

6.3.2.1 Each boiler is to be provided with two independent feed check valves. But for small vertical boilers and exhaust-gas boilers for non-essential service, one feed check valve may be accepted.

6.3.2.2 Each feed check valve is to consist of a screw-down valve and a non-return valve, the lift of non-return valve is to be adjustable. The screw-down valve is to be attached direct to the boiler. The non-return valve is to be adjacent to the screw-down valve wherever practicable. For boilers fitted with economizers, the screw-down valve may be attached direct to the economizer which forms an integral part of the boiler.

For water tube boilers, the feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily operated from the stoke hold floor or other convenient position.

6.3.2.3 For water tube boilers at least one of the feed water systems is to be fitted with an approved feed

water regulator whereby the water level in the boilers is controlled automatically.

6.3.3 *Feed standpipes and internal pipes*

6.3.3.1 For boilers having a design pressure more than 2.75 MPa, the standpipes for feed inlets are to be designed with an internal pipe with the object of minimizing thermal stresses where temperature differences occur between the feed pipe and boiler shell.

6.3.3.2 The internal pipes for feed inlets are to be so arranged that no feed water impinges directly on the inner surfaces of the boiler shell exposed to hot gases.

6.3.4 *Water level indicators*

6.3.4.1 Each boiler whose operation is designed at a specified water level is to be fitted with at least two water level indicators, one is to be a direct reading gauge glass, and the other may either be water gauge or other equivalent device (e.g. remote water level indicator).

6.3.4.2 The water gauges are to be readily accessible and so located that the water level is clearly visible. The lowest visible part of the glass water gauge is to be situated at the lowest safe working water level, but for water tube boilers, this level is to be situated at 50 mm below the lowest safe working water level.

In water tube boilers, where the steam and water drum exceeds 4 m in length and is fitted athwartships, one gauge glass is to be fitted in a suitable place at or near each end of the drum.

6.3.4.3 The water gauges are to be of flat glass type. Glass tube glass gauges with reliable protections may be used for boilers having a working pressure not exceeding 0.78 MPa.

Water gauge cocks are to be provided with operating gear if necessary and are to be so arranged that they can be easily operated without danger when the glass is damaged.

6.3.4.4 Water gauges are also to be provided with blow-off devices.

6.3.4.5 The water gauges may be fitted directly to the boiler shell or to columns, these columns are to be directly bolted or screwed to the boiler shells, or connected to the boiler by means of pipes. If they are connected by means of pipes, these pipes are to be fitted with cocks or screw-down valves with indicators showing whether the valves are open or shut. The internal diameter of the connecting pipes or columns is to be selected in accordance with Table 6.3.4.5.

Internal diameter of connecting pipes and columns *Table 6.3.4.5*

Internal dia. of boiler body (m)	Internal dia. of connecting pipes (mm)	Internal dia. of column (mm)
> 3	≥ 38	≥ 63
2.3~3	≥ 32	≥ 50
< 2.3	≥ 25	≥ 45

The connecting pipes which communicate with the steam space are to be so arranged that there is no pocket or bend where accumulation of condensate water can lodge. Connecting pipes are not to pass through the uptake; if, however, this requirement cannot be complied with, they may pass through the uptake by means of a pipe tunnel with at least 50 mm air gap clear of the pipe all round.

6.3.4.6 In general, the lowest water level in the boiler is to be as follows:

(1) For boilers with water tubes submerged when cold, the lowest water level is to be above the top row of tubes; for boilers with tubes not submerged when cold, the manufacturer is to submit the design information for the lowest level for consideration.

(2) The lowest water level in horizontal smoke tube boilers is not to be less than 75 mm above the top of combustion chambers or smoke tubes, but for multi-return flow smoke tube boilers, this level may be suitably lowered.

(3) The lowest water level in combined boilers is not to be less than 50 mm above the hot water tubes.

(4) The height of lowest water level in vertical boilers having vertical smoke tubes is not to be less than half the length of smoke tubes.

(5) The above mentioned heights of the lowest water level are to be still maintained when the ship has a list of 4°.

6.3.4.7 Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level alarm.

6.3.4.8 Smoke tube exhaust gas boilers are to be provided with a low level alarm device and an exhaust gas bypass or a standby feed water pump. An alarm is to be given and exhaust gas automatically (or manually) bypassed or the standby feed water pump automatically started in a low water level condition.

6.3.4.9 Water tube exhaust boilers with forced circulation are to be provided with a low water flow or low pressure alarm device and a standby water circulating pump. An alarm is to be given and the standby water circulating pump automatically started in a low water flow or low pressure condition.

6.3.5 *Safety valves*

6.3.5.1 Boilers are to be fitted with not less than two safety valves. For small auxiliary boilers one safety valve may be accepted. For boilers with superheaters, at least one safety valve is to be fitted on the superheater.

Where a superheater is fitted as an integral part of a boiler, viz. there is no stop valve fitted between the superheater and the boiler, the area of superheater safety valve may be included in the total area of boiler safety valves; and where a stop valve is fitted between the superheater and the boiler, the area of superheater safety valve is not to be included in the area of boiler safety valves.

The area of the superheater safety valve is, in general, to be 25% of the total area of boiler safety valves required.

6.3.5.2 The diameter d of safety valve seatings is to be determined by the following formula:

(1) For saturated steam:

$$d = \sqrt{\frac{DA}{n(10.2p+1)}} \quad \text{mm}$$

where: n – number of valves;

p – design pressure of boiler, as specified in 6.1.3.1 of this Chapter, in MPa;

D – maximum design evaporation of boiler, in kg/h;

A – coefficient, as given in Table 6.3.5.2.

Coefficient A *Table 6.3.5.2*

Lift (mm)	d/24	d/20	d/16	d/12	d/4
Coefficient A	27	23	18.5	14	6.6

(2) For superheated steam:

$$d_1 = d\sqrt[4]{\frac{V_g}{V_B}}$$

where: d_1 — diameter of valve seating for superheated steam, in mm;

d — diameter of valve seating as obtained in the calculation for saturated steam, in mm;

V_g — specific volume of superheated steam, in m^3/kg;

V_B — specific volume of saturated steam, in m^3/kg.

(3) The diameter of full lift safety valves determined by the formula specified above is based on the area not including that of the guides or other obstructions. Then, for full lift safety valves with guides or other obstructions, the diameter of safety valves is to be determined by the total area of valve seatings and guides or other obstructions.

(4) In any case, the valve seating diameter of a safety valve is not to be greater than 100 mm, nor less than 25 mm.

(5) If the diameter of any safety valve fitted on the boiler is less than that required by the Rules, such valve is to be confirmed by testing. The designer is to ensure that safety valves fitted on boilers comply with the testing requirements for safety valves in the Rules.

6.3.5.3 Test of boiler safety valves

(1) For smoke tube boilers with all stop valves closed and under full firing conditions, for a duration of 15 min after the safety valve blows, the maximum pressure value attained is not to exceed 110% of the design pressure.

(2) For water tube boilers under the same conditions described above, for a duration of 7 min after the safety valve blows, the maximum pressure value attained is not to exceed 110% of the design pressure.

(3) The boiler is not to be supplied with water during the test unless it is necessary to maintain the safe working water level.

6.3.5.4 The construction of boiler safety valves is to comply with the following requirements:

(1) The safety valves are to be so locked or sealed that after setting to the working pressure, they cannot be tampered with or overloaded in service, and that they are to be so designed that in the event of fracture of springs they can not lift out of their seats.

(2) The waste steam is not to come into direct contact with the loading springs.

(3) The safety valves are to be so secured to the shell that the passage area is not to be less than the total area of the safety valves in the case of full lift valves (lift $\geq d/4$), and one-half of that area in the case of other safety valves.

(4) Each safety valve chest is to be drained by a pipe led with a continuous fall to the bilge, and no valves or cocks are to be fitted to these drain pipes.
(5) Safety valves are to be provided with easing gear which is to be operable at a safe position from the boiler or engine room platforms.
(6) The spring casing of superheater safety valves are to be ventilated; or other arrangement provided to protect the springs from excessive temperature.
(7) Two safety valves may be fitted in one chest.
6.3.5.5 The safety valves are to be fitted directly to the boiler shell and superheater.
6.3.5.6 For full lift safety valves (lift $\geq d/4$), the passage area of the waste steam pipe is not to be less than twice the total area of safety valves, and for other type of safety valves. This passage area is not to be less than 1.1 times the total area of safety valves.
6.3.5.7 The setting pressure of boiler safety valves is not to be greater than the design pressure of the boiler. A setting pressure of safety valves to lift at not exceeding 103% of the design pressure is acceptable, taking into account the working tolerance.
The setting pressure of superheater safety valves is to be lower than that of the boiler safety valves.
6.3.5.8 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

6.3.6 *Stop valves*
6.3.6.1 The main and auxiliary stop valves are to be secured direct to the boiler shell. The number of auxiliary stop valves is to be minimized as far as practicable so as to minimize the unnecessary openings in the shell. Where the superheater is integral with the boiler, the main stop valve is to be fitted to the outlet of the superheater.
6.3.6.2 Where two or more main boilers or auxiliary boilers for essential services are connected together the following requirements are to be complied with:
(1) Essential services are to be capable of being supplied from at least two boilers.
(2) Stop valves of self-closing or non-return type are to be fitted.

6.3.7 *Blow-off and scum valves*
6.3.7.1 Each boiler is to be fitted with blow-off valves and, if necessary, scum valves. Both blow-off and scum valves (if fitted) are to be secured direct to the boiler shell. Where it is not practicable to attach the blow-off valve direct to water tube boilers, the valve may be placed immediately outside the boiler casing with a steel pipe of substantial thickness fitted between the boiler and valve.
6.3.7.2 Scum valves and blow-off valves are not to be less than 20 mm in diameter, nor to exceed 65 mm.
6.3.7.3 The top edge of scum pans for the surface blow-off is to be placed in the boiler within a range from 25 mm above the lowest water level to 25 mm below the working water level.
The number and arrangement of the scum pans are to be such as to ensure the possibility of blowing off the scum and oil from the entire evaporating surface.

6.3.8 *Pressure gauges*
6.3.8.1 Each boiler is to be fitted with at least one pressure gauge in an easily seen position.
6.3.8.2 The connecting tube for each pressure gauge is to be provided with a joint (including valve or cock) for check of the pressure gauge.
6.3.8.3 Pressure gauges are to be marked with a red line for indicating the working pressure of the boiler. The scale of pressure gauges is to be suitable for the hydraulic test pressure of boilers.

6.3.9 *Sampling valve or cock*
6.3.9.1 Each boiler is to be provided with a sampling valve or cock secured direct to the boiler shell. The valve or cock is not to be fitted on the water gauge standpipe.

6.3.10 *Air cocks*
6.3.10.1 An air valve or cock is to be fitted to the top of steam space of the boiler or drum and is to be, in general, 10 to 15 mm in diameter.

6.3.11 *Superheater mountings*
6.3.11.1 Superheaters are to be provided with the following mountings:
(1) safety valves as specified in 6.3.5.1 and 6.3.5.2 of this Section;
(2) stop valves as specified in 6.3.6.1 of this Section;
(3) drain valves;

(4) air cocks;
(5) thermometers.

6.3.12 *Fittings of shell type exhaust gas heated economizer*

6.3.12.1 All shell type exhaust gas heated economizers that may be isolated from the steam plant system in a flooded condition are to comply with the requirements 6.2.1.4, 6.2.12.1 and 6.3.12.2 to 6.3.12.6.

6.3.12.2 Where a shell type economizer is capable of being isolated from the steam plant system, it is to be provided with at least one safety valve, and when it has a total heating surface of 50 m^2 or more, it is to be provided with at least two safety valves.

6.3.12.3 To avoid the accumulation of condensate water on the outlet side of safety valves, the discharge pipes and/or safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

6.3.12.4 Every shell type economizer is to be provided with a means of indicating the internal pressure. A means of indicating the internal pressure is to be located so that the pressure can be easily read from any position from which the pressure may be controlled.

6.3.12.5 Every economizer is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

6.3.12.6 The manufacturer is to provide operating instructions for each economizer which is to include reference to:

(1) feed water treatment and sampling arrangements;
(2) operating temperatures – exhaust gas and feed water temperatures;
(3) operating pressure;
(4) inspection and cleaning procedures;
(5) records of maintenance and inspection;
(6) the need to maintain adequate water flow through the economizer under all operating conditions;
(7) periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly;
(8) procedures for using the exhaust gas economizer in the dry condition;
(9) procedures for maintenance and overhaul of safety valves.

Section 4 FITTINGS OF PRESSURE VESSELS

6.4.1 *Fittings*

6.4.1.1 Each pressure vessel is to be provided with the following fittings (for air receivers, see 6.4.1.2 of this Section):

(1) stop valves are to be fitted at the inlet and outlet of the pressure vessels, which are to be secured direct to the cylindrical shell as far as possible;
(2) drain devices including valves and internal pipes (where applicable);
(3) safety devices for preventing overpressure (safety valves are to comply with the requirements of 6.4.1.2(4) of this Section, if fitted);
(4) pressure gauges indicating the medium pressure (where applicable);
(5) level indicators showing the working level of medium (where applicable).

6.4.1.2 Each air receiver is to be provided with the following fittings:

(1) stop valves and pressure gauges as described in 6.4.1.1(1) and (4) of this Section;
(2) drain devices as specified in 6.4.1.1(2) of this Section, which are to be so arranged that they can drain completely the water from the lowest portion of the air receiver;
(3) safety valves. Where the air inlet pipe or the air compressor is fitted with a safety valve capable of preventing the pressure in the air receiver under charging conditions from exceeding the design pressure, the safety valve on the air receiver may be dispensed with, provided that a fusible plug with a melting point approximately at 100℃ and of a size capable of releasing the air in the event of fire is provided;
(4) the capacity of safety valves are to ensure that the air pressure is not to exceed 110% design pressure. Where outlet valves are closed, control valves are to be provided with safety valves.

6.4.1.3 Open drain system is normally to be taken for air receiver. Where closed drain system is taken, due consideration is to be given in design to the possibility of pressure accumulation within the system caused by the blockage of drainage outlet of port by oil/water, and the system has sufficient strength to

withstand the maximum pressure of air receiver.

Section 5 THERMAL OIL HEATERS

6.5.1 *General provisions*

6.5.1.1 This Section applies to thermal oil heaters in which thermal oils are heated to temperatures below their initial boiling point at atmospheric pressure.

6.5.1.2 The detailed requirements for thermal oil systems are given in Section 8, Chapter 4 of this PART.

6.5.2 *Materials and welding*

6.5.2.1 The materials and welding of thermal oil heaters are to comply with the requirements for boilers in this Chapter.

6.5.2.2 Copper and copper alloys are not to be used so as to prevent oxidation of thermal oil.

6.5.3 *Design and manufacture*

6.5.3.1 Thermal oil heaters are to be designed and manufactured in accordance with the requirements for boilers in this Chapter.

6.5.3.2 The surfaces which come into contact with the thermal oil are to be designed for the maximum allowable working pressure, subject to a minimum gauge pressure of 0.6 MPa.

6.5.3.3 Different thermal oil heaters are to be provided with inspection holes as follows:

(1) oil fired heaters are to be provided with inspection holes for examination of the combustion chamber;

(2) exhaust-gas thermal oil heaters are to be provided with manholes serving as inspection holes at the exhaust gas intake and outlet.

6.5.4 *Fittings of thermal oil heaters*

6.5.4.1 Each heater is to be equipped with at least one safety valve complying with the following:

(1) having a blow-off capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During blow-off, the pressure is not to exceed 110 % of the design pressure of the heater;

(2) the discharge pipe of safety valves is to be led to a thermal oil collecting tank with suitable capacity.

6.5.4.2 Thermal oil heaters are to be provided with means enabling the thermal oil to be completely drained.

6.5.4.3 Thermal oil heaters are to be provided with means to sample the thermal oil.

6.5.4.4 Thermal oil heaters are to be fitted with the following temperature and flow (or pressure) indicators:

(1) thermal oil temperature measuring devices are to be fitted at the thermal oil discharge line of both oil fired heaters and exhaust-gas thermal oil heaters;

(2) devices indicating the flow or pressure of the thermal oil are to be fitted in the thermal oil circulation system.

6.5.4.5 The gas outlet of exhaust-gas thermal oil heaters are to be provided with a temperature sensor and an alarm device for fire detection.

6.5.4.6 Thermal oil heaters are to be provided with means to monitor leakage in accordance with the following requirements:

(1) oil fired heaters are to be provided with a leakage detector which stops the burner and blocks the starting of burner when leakage of thermal oil is detected. If the thermal oil heater is ready to start, when leakage of thermal oil is detected, the starting of burner is to be blocked;

(2) exhaust-gas thermal oil heaters are to be provided with a leakage detector which triggers an alarm when leakage of thermal oil is detected.

6.5.4.7 Heating surfaces of exhaust-gas thermal oil heaters are to be provided with a fixed fire-extinguishing system and a cooling system. Where a pressure water spray system is fitted for this purpose, the following requirements are to be complied with:

(1) the flow rate of the water spraying system is to be at least 5.0 *l*/min for each square meter of the heating surface, and water supply is to be available for at least 20 min;

(2) nozzles are to be so arranged that the required amount of water is sprayed on the entire heating surface;

(3) suitable means for water collection and drainage are to be provided for the exhaust gas line below the heater so as to prevent water entering into engines;

(4) all means of starting valves and pumps necessary for the operation of the water spraying system are to be fitted in an easily accessible place at a safe distance from the heater so as to facilitate the operation by

the personnel in case of the heater catching fire;
(5) concise operating instructions are to be permanently displayed at the operating position of the system.

6.5.5 *Monitoring and protection*

6.5.5.1 Monitoring and protective measures are to be provided for thermal oil heaters according to Table 6.5.5.1.

Monitoring and Alarm Items for Thermal Oil Heaters *Table 6.5.5.1*

Items to be monitored	Local control			Remark
	Indication	Alarm	Automatic shutoff	
Thermal oil expansion tank level	×	Low	×	
Thermal oil flow or pressure	×	Low	×	
Thermal oil outlet temperature	×	High	×	
Combustion air pressure or forced ventilation①		Low or shutoff	×	
Oil fuel pressure①	×	Low		Standby pumps to start automatically
Heavy oil fuel temperature or viscosity①	×	Low and great		For heavy oil fuel only
Uptake temperature①	×	High	×	
Burner flame or ignition①		Flameout/failure	×	Each burner to be monitored
Exhaust temperature②	×	High		

Notes:
× = functional requirement
① Applicable for oil-fired heaters.
② Applicable for exhaust gas heaters.

Section 6 INSTALLATION AND TEST

6.6.1 *Installation of boiler*

6.6.1.1 The boilers are to be securely fixed on board, and the boiler stools and upper part of cylindrical shell are to be secured in such a way as to be able to adapt the thermal expansion of the drums and headers.

6.6.2 *Hydraulic tests*

6.6.2.1 On completion of manufacture or assembly, boilers, boiler components and mountings, fittings, thermal oil heaters and pressure vessels are to withstand hydraulic tests in accordance with Table 6.6.2.1, but test pressure is not to exceed 90% yield force under test temperature.

Hydraulic Test *Table 6.6.2.1*

No.	Name		Test pressure (MPa)	
			On completion of manufacture or assembly	After installation of fittings
1	Drums, header, economizer header		1.5 p	–
2	Overheater header	Working temperature ≤ 350℃	1.5 p	–
		Working temperature > 350℃	$1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$	–
3	Boiler, overheater, economizer, thermal oil heater		1.5 p	1.25 p
4	Pressure vessel	Working temperature ≤ 350℃	1.5 p	1.25p (air receiver may be used for gastight test under work pressure)
		Working temperature > 350℃	$1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$	
5	Boiler gas pipe, water pipe, overheat pipe and economic pipe		2 p (after bending)	–
6	Overheat steam valve		2.5 p	1.5 p
7	Other boiler valves or fittings		2 p	1.25 p

Notes:
① p — design pressure, in MPa;
② R_{eH}^{350} — specified minimum yield point or 0.2 per cent proof stress of material at 350°C, in N/mm^2;

③ R_{eH}^{T} — specified minimum yield point or 0.2 per cent proof stress of material at the working temperature t (°C), in N/mm^2.

6.6.2.2 Where all components of a boiler, such as drums, headers, etc., have been satisfactorily tested to 1.5 times the design pressure or $1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$, on completion of fabrication including attachment of standpipes and pads by welding and heat treatment (but before drilling the tube holes), the boiler may be tested only to 1.25 times the design pressure.

6.6.3 *Shipboard trials*

6.6.3.1 All boilers or thermal oil heaters are to be functionally tested in operation and safety devices after installation.

6.6.3.2 Pressure vessels are to be functionally tested with the systems in which they form a part.

Appendix 1 STRENGTH CALCULATION OF WATER TUBE BOILERS

1 *Cylindrical shells*

1.1 The minimum thickness of the cylindrical shell and tube plate of steam or water drums is to be determined by the following formula:

$$\delta = pD_0/(2[\sigma]\varphi + p) + 0.75 \quad \text{mm}$$

where: p — design pressure of boiler as specified in 6.1.3.1(1) of this Chapter, in MPa;
D_0 — inside diameter of cylindrical shell, in mm;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;
φ — minimum strength factor of cylindrical shell, to be determined in accordance with 2.1 of this Appendix.

This formula is applicable only where the resulting thickness does not exceed 0.5 times the inner radius of cylindrical shell.

1.2 The minimum thickness of a cylindrical shell of boilers is not to be less than 6.0 mm.

1.3 For tube plates, such thickness as will give a minimum parallel seat of 9.5 mm, or such greater width as may be necessary to ensure tube tightness (see 6.2.11 of this Chapter).

2 *Strength factor of cylindrical shell*

2.1 The strength factor φ of the cylindrical shell is to be determined as follows:

(1) For welded cylindrical shell unweakened by the tube holes, the strength factor $\varphi$is to be the same as the joint factor φ' of the welded seam given in Table 6.2.6.1 of this Chapter. For seamless cylindrical shell, $\varphi$is equal to 1.

(2) Strength factor of cylindrical shell weakened by the tube holes is to be determined as follows:

① For tube holes of same diameter disposed with regular staggered spacing or regular drilling and having the same pitch in longitudinal direction as shown in Figure 2.1(2)① and Figure 2.1(2)③, the strength factor φ_1 of cylindrical shell is to be determined by the following formula:

$$\varphi_1 = \frac{t_1 - d}{t_1}$$

② For tube holes of same diameter disposed with regular staggered spacing (the holes in any row are shifted in relation to those in the adjacent row by half a pitch in longitudinal direction) and having the pitch both in longitudinal and transverse directions as shown in Figure 2.1(2)①, the strength factor φ_2 of cylindrical shell in longitudinal direction converted from that in diagonal direction is to be determined by the following formula:

$$\varphi_2 = K\varphi_k$$

where: $K = \dfrac{1}{\sqrt{1 - \dfrac{0.75}{(1+m^2)^2}}}$, or to be taken according to Figure 2.1(2)②;

where: $m = \dfrac{t_1}{t_2}$;

$$\varphi_k = \frac{t_k - d}{t_k}.$$

The strength factor φ of cylindrical shell is to be selected from either of the above two values obtained from ① and ②, whichever is the smaller.

③ For tube holes of same diameter disposed with regular drilling as shown in Figure 2.1(2)③, if the pitch t_2 in transverse direction is smaller than pitch $t_1/2$ in longitudinal direction, the strength factor of cylindrical shell is to be taken as 2 φ_3 instead of φ_1 as determined by 2.1(2)①. φ_3 is to be determined by the following formula:

$$\varphi_3 = \frac{t_2 - d}{t_2}$$

The tube pitch t_2 in transverse direction is to be the pitch in way of the centre surface of tube holes.

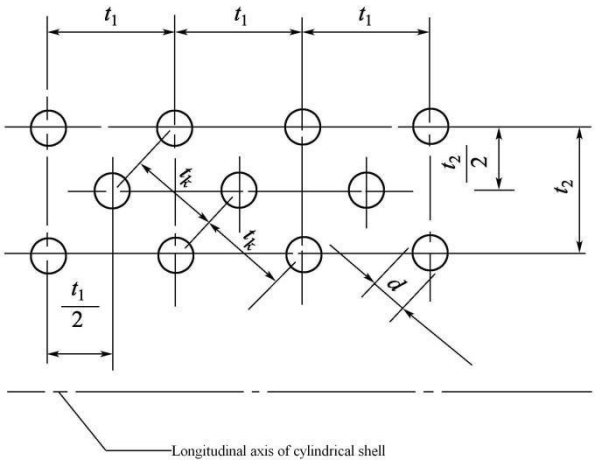


Figure 2.1(2)①

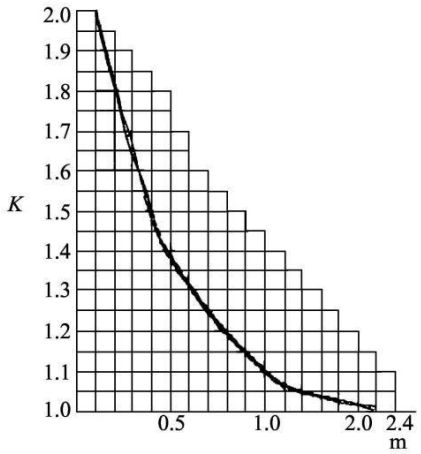


Figure 2.1(2)②

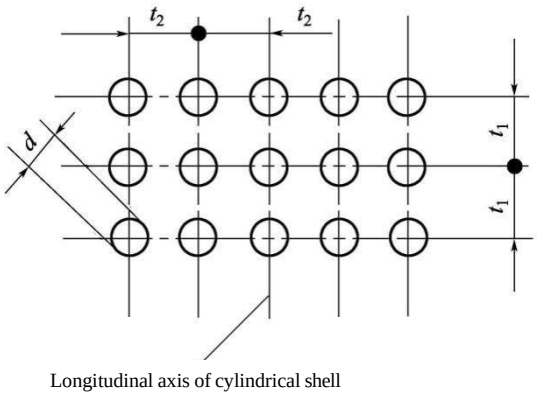


Figure 2.1(2)③

2.2 For tube holes of same diameter with distance between centres adjacent tube holes not constant, as shown in Figure 2.2, the strength factor φ_1 of cylindrical shell is to be determined by the following formula:

$$\varphi_1=\frac{t_1+t'-2d}{t_1+t_1'}$$

In such a case, the double pitch $t_1+t'_1$ chosen is to be that which makes a minimum φ_1, and in no case t'_1 is to be taken as greater than $2t_1$.

2.3 Where tube holes of two different diameters are alternately disposed, the diameter of tube holes is to be replaced by the mean value of the diameters.

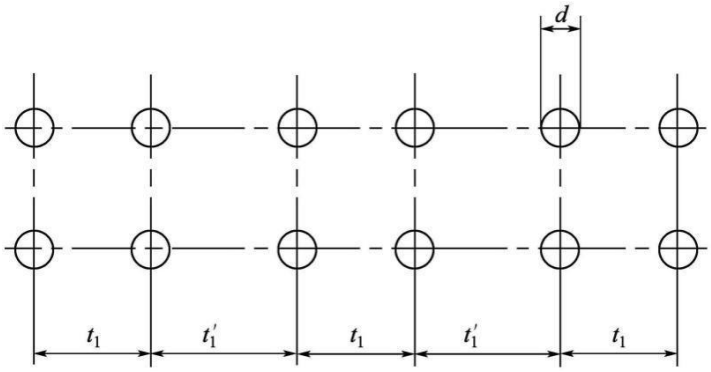


Figure 2.2

3 Compensating effect of tube stubs

3.1 Where a drum or header is drilled for tube stubs fitted by strength welding (see 1.3 of Appendix 5 of this Chapter), the effective diameter of holes used for calculation of the strength in hole line may be replaced by equivalent diameter dc of holes, which is to be taken as:

$$d_c = d - \frac{A}{\delta} \quad \text{mm}$$

where: d — the actual diameter of the hole, in mm;

δ— the thickness of the shell, in mm;

A — the compensating area provided by each tube stub and its welding filets, in mm^2 as shown in Figure 3.1(1) or (2), (the area in the shade line is a half compensating area A), in which:

δ_1 — actual thickness of the tube stub, in mm;

δ_3 — minimum thickness of the tube stub required in 9.1 of this Appendix, in mm;

$h = \sqrt{d\delta_1}$, in mm.

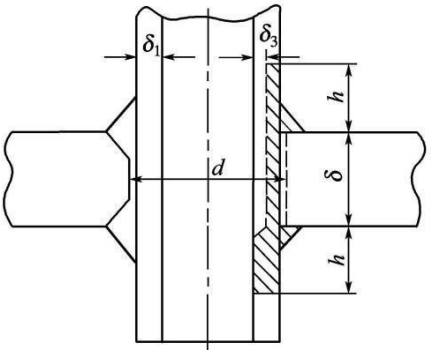


Figure 3.1(1)

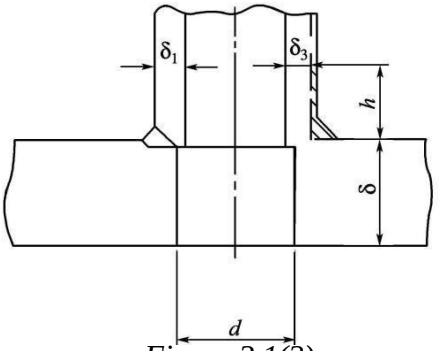


Figure 3.1(2)

3.2 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the following ratio for correction:

allowable stress of stub at design temperature;

allowable stress of shell at design temperature.

4 *Spherical shells*

4.1 The minimum thickness $\delta$of spherical shells subject to internal pressure is to be determined by the following formula:

$$\delta = \frac{pD_0}{4[\sigma]\varphi - p} + 0.75 \quad \text{mm}$$

where: D_0 — inside diameter of the shell, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

[σ]— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter , in N/mm^2;

φ— strength factor of shell, to be taken in accordance with joint factor of welded seam given in Table 6.2.6.1 of this Chapter.

Spherical shells with openings are to be reinforced in accordance with 2.1 to 2.3 in Appendix 5 of this Chapter.

The above mentioned formula is applicable only where the resulting thickness does not exceed half the internal radius of the shell.

5 *Dished ends*

5.1 The minimum thickness δ of ellipsoidal, torispherical and hemispherical end plates subject to pressure on the concave side, as shown in Figures 5.1(1) to (3), is to be determined by the following formula:

$$\delta = \frac{pD_1 y}{2[\sigma]\varphi} + 0.75 \quad \text{mm}$$

where: D_1 — outside diameter of end plate, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

[σ]— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

φ — applying to joint factor of welded seam or the minimum strength factor of drum shell (see 2 in

this Appendix);

y — shape factor, to be obtained from Figure 5.1(4).

For ends without openings, the value of y is to be selected from the group of solid curves, dependent on the ratio of δ/D_1 and H/D_1.

For ends with unreinforced openings, the value of y is selected from the group of dotted curves, dependent on the ratio of $d/\sqrt{D_1\delta}$ and H/D_1, where: d – the diameter of the largest opening in the end plates, in mm (in the case of an elliptical opening, the major axis of the ellipse is to be taken).

For openings with effective reinforcement, the opening factor may be determined according to 2.1 in Appendix 5 of this Chapter. The location of openings and construction of dished ends are to comply with the requirements of 5.2 and 5.3 in this Appendix.

Where the ends are made from more than one plate and welded, the minimum thickness determined by above formula is to be modified by taking account of the joint factor according to 6.2.6.1 of this Chapter.

For ends which are butt welded to the drum shell, the thickness of the edge of the flange for connection to the shell is not to be less than the thickness of an unpierced seamless or welded shell, whichever is applicable, determined in 1.1 of this Appendix.

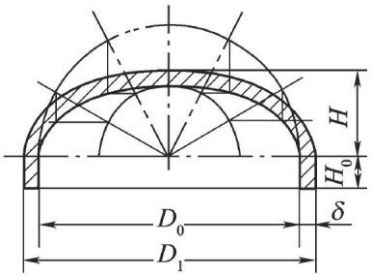


Figure 5.1(1) Ellipsoidal end

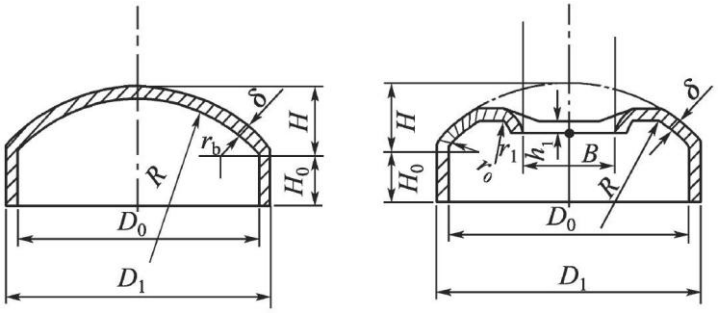


Figure 5.1(2) Torispherical end

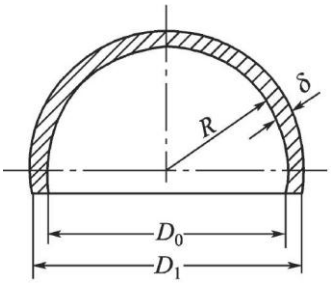


Figure 5.1(3) Hemispherical end

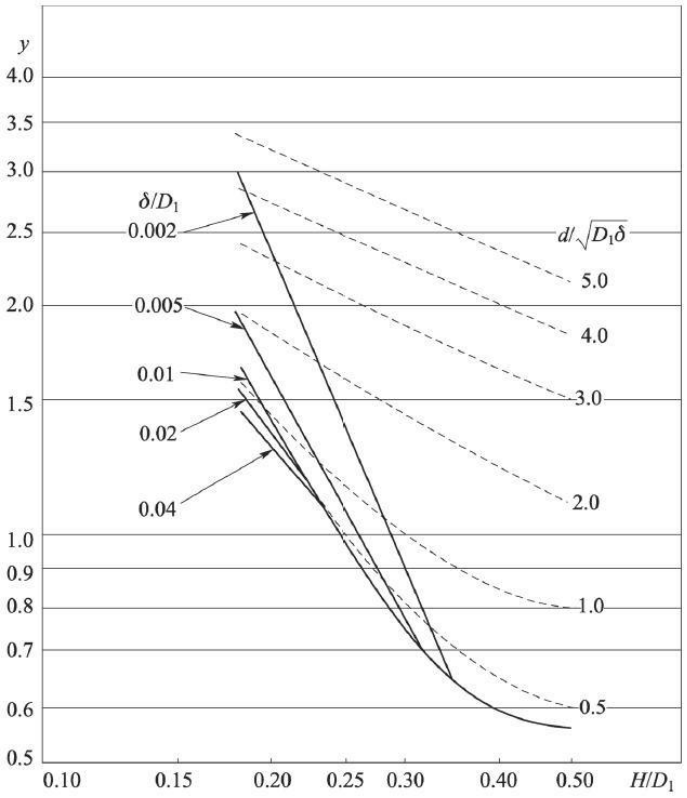


Figure 5.1(4)

5.2 Openings in ellipsoidal and torispherical ends are to be in accordance with the following requirements, as shown in Figure 5.2.

(1) The projectional distance from the edge of hole to the outside edge of the end plate is not to be less than $0.1D_1$.

(2) The projectional distance between two adjacent openings is not to be less than the diameter of the smaller opening.

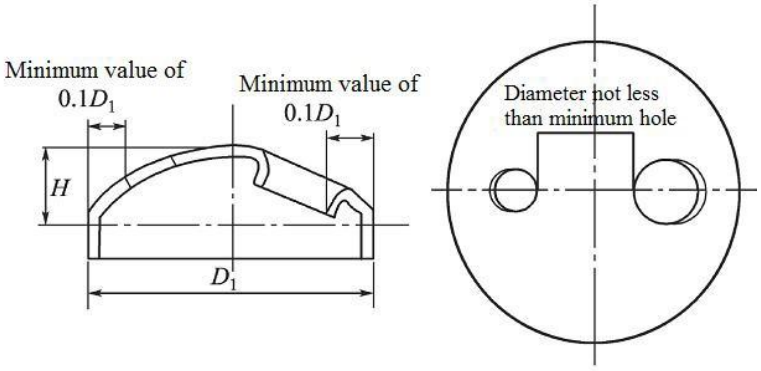


Figure 5.2

5.3 The construction of dished ends is to comply with the following requirements:

(1) For torispherical ends, see Figure 5.1(2) of this Appendix:

$r_b \geq 0.1D_1$ or $r_b \geq 3\delta$, whichever is the greater,

$R \leq D_1$; $H \geq 0.18D_1$ and $H_0 \geq 2\delta$.

(2) For ellipsoidal ends, see Figure 5.1(1) of this Appendix:

$H \geq 0.20D_1$; $H_0 \geq 2\delta$.

(3) For manhole flanges in ellipsoidal, torispherical and hemispherical ends, (in no case is the manhole flange to be taken as the opening reinforcement.), see Figure 5.1 (2) of this Appendix:

$h_1 \geq \sqrt{B\delta}$, where B is the minor axis of manhole;

r_1 = (1.5 to 2) δ.

5.4 The minimum thickness of a dished end is not to be less than 6.0 mm.

6 *Conical ends subject to internal pressure*

6.1 For the construction of conical ends and conical reducing sections, see Figures 6.1(1) to 6.1(4). Connections between cylindrical shell and conical sections and ends are preferably to be by means of a knuckle transition radius. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope ψ between the two sections under consideration does not exceed 30°C.

Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

The minimum thickness of conical ends or sections is to be determined by the formulae specified in 6.2 and 6.3 of this Appendix, but the thickness of plates at the knuckle and within the distance L from the knuckle is not to be less than the thickness of the section to which it is connected.

6.2 The minimum thickness δ of the cylinder, knuckle and conical end or section at the junction and within the distance L (see Figure 6.1 of this Appendix) from the junction is to be determined by the following formula:

$$\delta = \frac{pD_1K}{2[\sigma]\varphi'} + 0.75 \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D_1 — outside diameter of the cylinder, conical end or section, in mm, see Figures 6.1(1) to (4);

φ' — joint factor of welded seam, to be selected in accordance with Table 6.2.6.1 of this Chapter. Where the distance of a circumferential seam from the knuckle or junctions is not greater than L. φ' is to be taken 1.0, otherwise, φ' is to be taken as the weld factor appropriate to the circumferential seam;

K — a factor, see Table 6.2;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

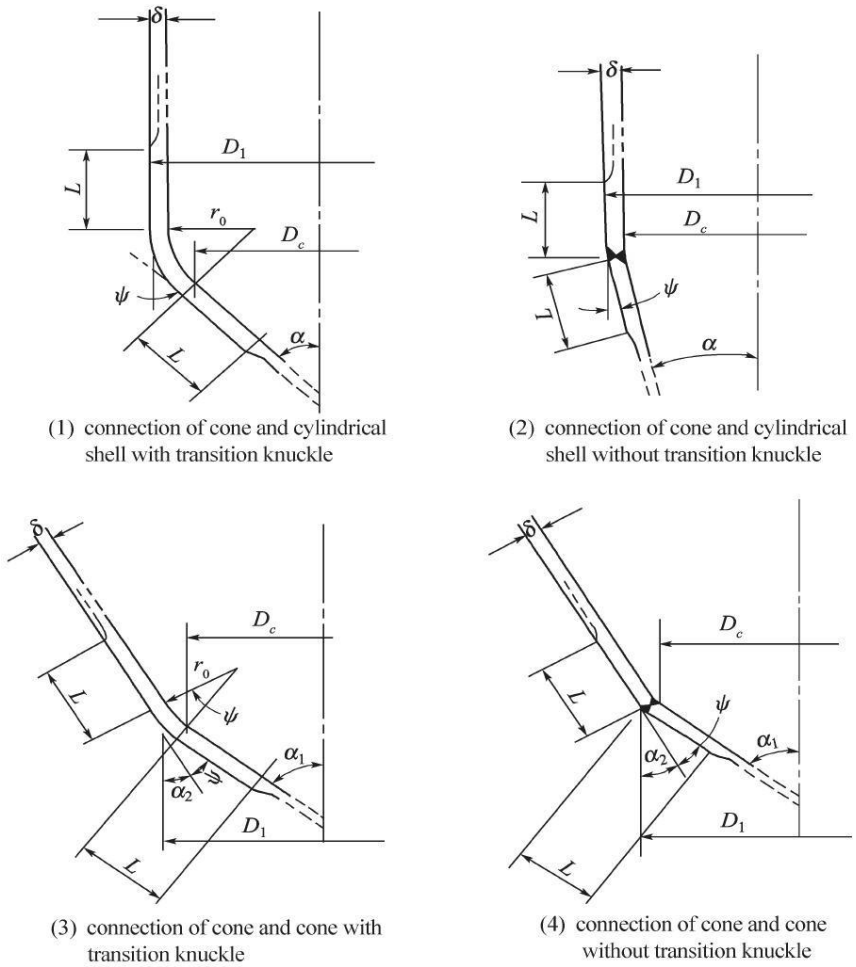


Figure 6.1

Factor *K* **Table 6.2**

r_0/D_1 / ψ	*K* corresponding to r_o / D_1											
	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.15	0.20	0.30	0.40	0.50
10°	0.70	0.65	0.60	0.60	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
20°	1.00	0.90	0.85	0.80	0.70	0.65	0.60	0.55	0.55	0.55	0.55	0.55
30°	1.35	1.20	1.10	1.00	0.90	0.85	0.80	0.70	0.65	0.55	0.55	0.55
45°	2.05	1.85	1.65	1.50	1.30	1.20	1.10	0.95	0.90	0.70	0.55	0.55
60°	3.20	2.85	2.55	2.35	2.00	1.75	1.60	1.40	1.25	1.00	0.70	0.55
75°	6.80	5.85	5.35	4.75	3.85	3.50	3.15	2.70	2.40	1.55	1.00	0.55

Note: r_0 — inside radius of transition knuckle, in mm, which is to be taken as 0.01 D_c in the case of conical sections without knuckle transition.

The distance L mentioned in this paragraph, as shown in Figures 6.1(1) to (4) of this Appendix, is to be determined by the following formula:

$$L = 0.5\sqrt{\frac{D_1\delta}{\cos\psi}} \qquad \text{mm}$$

where: ψ — difference between angle of slope of two adjoining conical sections, see Figure 6.1 of this Appendix.

6.3 The minimum thickness δ of those parts of conical sections not less than a distance L from the junction with a cylinder or other conical section is to be determined by the following formula:

$$\delta = \frac{pD_c}{2[\sigma]\varphi' - p} \cdot \frac{1}{\cos a} + 0.75 \qquad \text{mm}$$

where: D_c — inside diameter, in mm, of conical section or end at the position under consideration, see Figures 6.1(1) to (4) of this Appendix;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

φ' — joint factor of welded seam, to be selected in accordance with Table 6.2.6.1 of this Chapter;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

α — angle of slope of conical section to the vessel axis e.g. α, α_1, α_2, as shown in Figures 6.1(1) to (4). The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

7 *Headers*

7.1 The minimum thickness for cylindrical shells of circular section headers is to be calculated in accordance with the requirements of 1.1 of this Appendix.

7.2 The minimum thickness of rectangular section headers is to be determined by the following formulae, the greater of two thicknesses obtained taken:

(1) thickness at the corner of the header:

$$\delta = \frac{p\sqrt{m^2 + l^2}}{2.6[\sigma]} + \sqrt{\frac{4.5M_k p}{[\sigma]}} \qquad \text{mm}$$

(2) thickness at flat surfaces of the header:

$$\delta = \frac{pl}{2.6[\sigma]\varphi} + \sqrt{\frac{4.5M_b p}{[\sigma]\varphi_1}} \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

m — half the clear width of the header wall to which the strength calculations are made, in mm;

l — half the clear width of another wall of the header, in mm;

M_k — factor of bending moment at the corner of the header, in mm^2:

$$M_k = \frac{1}{3}\frac{m^3 + l^3}{m + l}$$

M_b — factor of bending moment at the flat surface of the header, in mm^2, use the absolute value for negative:

$$M_b = M_k - (m^2 - b^2)/2$$

b — distance measured from the center line of weaken holes to axis of header, in mm, see Figure

7.2(1);

φ,φ_1 — strength factor:

$$\varphi = \frac{t-d}{t}$$

$$\varphi_1 = \varphi \quad \text{when} \quad \frac{d}{m} < 0.6$$

$$\varphi_1 = 1 - 0.6\frac{m}{t} \quad \text{when} \quad \frac{d}{m} \geq 0.6$$

where: t — pitch between holes, in mm;

d — diameter of holes in the header, in mm. For elliptical holes, the value d adopted in $\varphi = (t-d)/t$ is to be replaced by the dimension a in a direction parallel to the longitudinal axis of the header, and value d in d/m is to be replaced by the dimension c in transverse direction, see Figure 7.2(2).

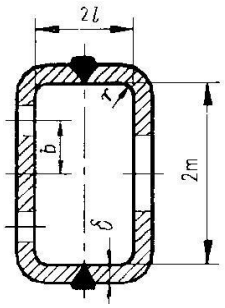


Figure 7.2(1)

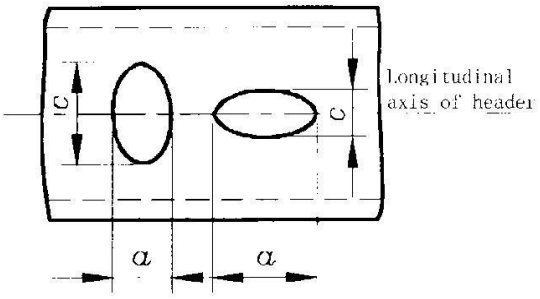


Figure 7.2(2)

7.3 Where the tube holes in the header are disposed with regular staggered spacing symmetrical to the center line of the header (see Figure 7.3), in addition to the calculation of header thickness in accordance with 7.1 or 7.2 of this Appendix, the thickness δ at the diagonal line of tube holes is to be calculated in accordance with the following formula:

$$\delta = \frac{pl}{2.6[\sigma]\varphi_k} + \sqrt{\frac{4.5M_b' p}{[\sigma]\varphi_k}} \quad \text{mm}$$

where: $M_b' = \left[\frac{m^3 + l^3}{3(m+l)} - \frac{m^2}{2}\right]\cos\alpha$;

$\varphi_k = \frac{t_k - d}{t_k}$;

α, t_k — see Figure 7.3.

Other symbols are as defined in 7.2 of this Appendix.

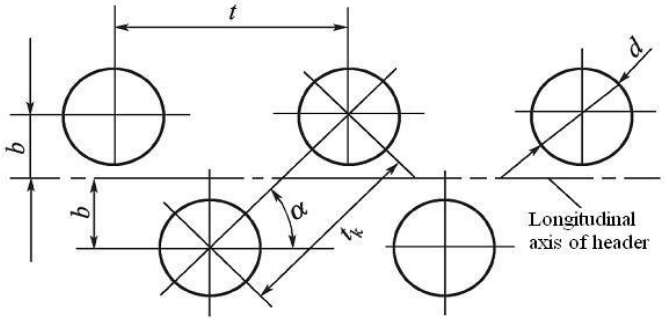


Figure 7.3

7.4 The radius r at the corner of the header, (as shown in Figure 7.2(1)) of this Appendix, is not to be less than 8 mm. Where the header wall is weakened by tube holes, the strength factor φ or φ_k is, as a rule, not to be less than 0.325. The minimum header wall thickness is not to be less than 8 mm, where tubes are fitted by expanding, the minimum header wall thickness is not to be less than 14 mm.

7.5 In welded headers, the distance measured from the center of tube holes to the edge of the welded

seam is not to be less than 0.9 times the diameter of hole, and openings in the welded zone are to be avoided as far as practicable.

8 *Flat end plates*

8.1 The minimum thickness δ of flat end plates is to be determined by the following formula:

$$\delta = CD\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;
D — calculated diameter of cylindrical shell, in mm;
c — constant, to be selected in accordance with Table 8.1.

In the case of rectangular flat end plates, the diameter D for calculations to be replaced by an equivalent diameter determined by the following formula:

$$D = a\sqrt{\frac{2}{1+(\frac{a}{b})^2}}$$

where: a — length of short side of rectangular end plate, in mm;
b — length of long side of rectangular end plate, in mm.

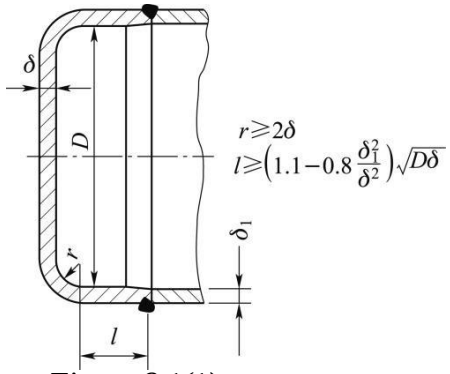


Figure 8.1(1)

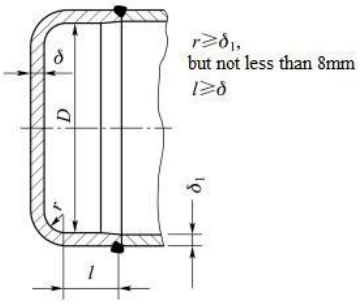


Figure 8.1(2)

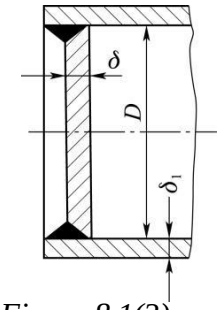


Figure 8.1(3)

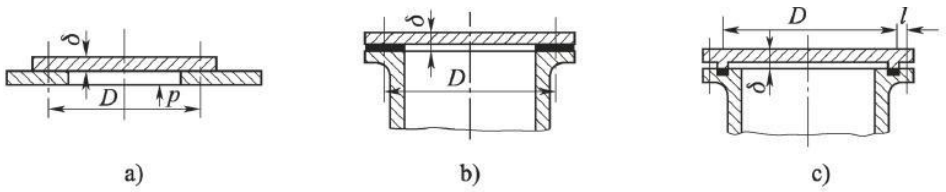


Figure 8.1(4)

Constant *C* **Table 8.1**

Type of end plate	Circular flat end plate *C*	Rectangular flat end plate *C*
Figure 8.1(1)	0.38	–
Figure 8.1(2)	0.43	0.50
Figure 8.1(3); Figure 8.1(4)(a); Figure 8.1(4)(b)	0.52	0.57
Figure 8.1(4)(c) *l*/D = 0.05 *l*/D = 0.10 *l*/D = 0.15	 0.57 0.62 0.67	 – – –

8.2 For circular flat end plates with openings, the minimum thickness of flat end plates is to be increased by 12% of the thickness required in 8.1 of this Appendix.

9 *Boiler tubes subject to internal pressure*

9.1 The minimum wall thickness δ of boiler tubes subject to internal pressure is to be determined by the following formula, but is in no case to be less than that required in 9.2 of this Appendix:

$$\delta = \frac{pD_1}{2[\sigma] + p} + 0.75 \qquad \text{mm}$$

where: D_1 — outside diameter of tubes, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

9.2 For boiler tubes calculated by 9.1 of this Appendix, the thickness is in no case to be less than the minimum thickness as given in Table 9.2, and in addition, provision is to be made for minus tolerances of tubes, bending allowances and abnormal corrosion which might be expected in service.

Minimum thickness of boiler tubes *Table 9.2*

Outside diameter of tubes	Minimum thickness	Outside diameter of tubes	Minimum thickness
≤ 38	1.75	> 75 ≤ 95	3.05
> 38 ≤ 50	2.16	> 95 ≤ 100	3.28
> 50 ≤ 70	2.40	> 100 ≤ 125	3.50
> 70 ≤ 75	2.67		

Note: For water tubes subject to internal pressure used for smoke tube boilers and vertical auxiliary boilers, the minimum thickness is not to be less than 3 mm.

Appendix 2 STRENGTH CALCULATION OF HORIZONTAL SMOKE TUBE BOILERS

1 *Cylindrical shell*

1.1 The minimum thickness of the cylindrical shell is to be determined in accordance with 1.1 in Appendix 1 of this Chapter.

1.2 Where the cylindrical shell is made of two sections, the longitudinal welded seams of the two sections are to be shifted for a distance at least 200 mm apart.

1.3 Where the steam dome is connected to the boiler shell by fillet welding, groove welding on both sides or groove welding on one side with sealing run is to be used.

2 *Stayed flat surfaces*

2.1 For flat plates supported by welded-in stays or by welded-in stays and flange connection, the minimum thickness δ is to be determined by the following formula:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p – design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$– allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

C – constant, to be selected in accordance with Table 2.1 of this Appendix;

t – calculated pitch of points of support, in mm.

(1) Where the stays are regularly pitched, see Figure 2.1(1):

$$t = \sqrt{a^2 + b^2}$$

(2) Where the stays are irregularly pitched, or within the area enclosing the stays and flanges: When a circle is drawn through three points of support with a result of centre of the circle being situated inside the triangle formed by these three points, $t = d$, see Figure 2.1(2).

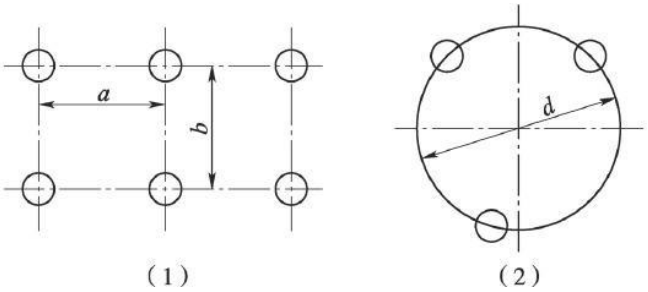


Figure 2.1

Constant *C* **Table 2.1**

Serial No.	Method of support	Constant C②	
		Not exposed to flame	Exposed to flame
1	Flange or fillet welding①	0.38	0.41
2	Stays, with gasket reinforcement, diameter of gasket ≥ 0.67 times stay spacing	0.36	—
3	Stays, with gasket reinforcement, diameter of gasket > 3.5 times diameter of stay	0.38	—
4	Stays, without gasket reinforcement, double-side welded	0.40	0.44
5	Stays, without gasket reinforcement, single-side welded	0.42	0.46
6	Stay tubes	0.46	0.51
7	Smoke tubes (within tube nests)	0.55	0.61

Notes: ① See 3.1(2), (3) and (4) of this Appendix.

② Where a flat plate is provided with two or more methods of support, the constant C is to be taken as the mean of the values for the respective methods adopted.

2.2 The minimum thickness δ of the flat tube plates within the tube nests is to be determined by the following formula:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

C — constant, to be selected in accordance with Table 2.1 of this Appendix, for methods of support, see Figure 4.2 (smoke tubes) and Figure 5.2 (stay tubes) of this Appendix;

t — mean pitch of stay tubes or smoke tubes, in mm.

(1) Where the stay tubes are welded to and the smoke tubes are expanded on the tube plates within the tube nests: t = mean pitch of stay tube supporting tube plates (equal to 1/4 the sum of the sides of a quadrangle formed by four tube centers).

(2) Where the smoke tube are all welded to the tube plates and without stay tubes within the tube nests: t = mean pitch of smoke tubes.

The minimum thickness of tube plates is in no case to be less than the following values:

(1) 10 mm where the tubes are welded to the tubes plates;

(2) 14 mm where the tubes are expanded on the plates; for auxiliary boilers with a design pressure not exceeding 0.78 MPa, 12 mm may be accepted.

2.3 The minimum thickness δ of the flat tube plates in the wide water spaces between tube nests or around tube nests is to be determined by the following formulae:

(1) For wide water spaces between tube nests:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \qquad \text{mm}$$

(2) For flat tube plates around tube nests:

$$\delta = Cd\sqrt{\frac{p}{[\sigma]}} + 0.75 \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

C — constant, to be selected in accordance with Table 2.1 of this Appendix; for method of support of stay tubes, see Figures 5.2(1) and (2) of this Appendix;

t $= \sqrt{a^2 + b^2}$, in mm

where: a — horizontal pitch of stay tubes, in mm;

b — vertical pitch of stay tubes, in mm;

d — diameter of the maximum circle passing through three points of support of stay tubes and flanges, or of stay tubes and stays, or of stay tubes, stays and flanges, with a result of the centre of the circle being situated inside the triangle formed by these three points, in mm.

2.4 For tube plates the support afforded by the smoke tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes. If the distance between the outside of the wing row of smoke tubes and point of support of flanges is less than the width of margin of flat plate determined in accordance with 2.5 of this Appendix, stay tubes may not be fitted in the wing row.

2.5 For a plate supported by the flues, furnaces or shell, the range from the point of support (see 3 of this Appendix) to the width of margin b obtained by the following formula may be regarded as being supported by the flues, furnaces or shell to which the flat plate is attached:

$$b = \frac{C(\delta - 1)}{\sqrt{p}} \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

δ — thickness of flat plates, in mm;

C = 9.7 for plates not exposed to flame;

C = 9.1 for plates exposed to flame.

Where an unflanged flat plate is welded directly to the flues, furnaces or shell and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula mentioned above is to be:

C = 7.5 for plates not exposed to flame;

C = 7.1 for plates exposed to flame.

2.6 In addition to the requirements of 2.2 and 2.3 of this Appendix, the minimum thickness δ of combustion chamber tube plates under compression, due to the load on the top plates, is to be checked by the following formula:

$$\delta = \frac{pLt}{193(t-d)} \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
L — length at the top of combustion chamber along axis of the boilers, measured from the tube plate to the back chamber plate, in mm;
t — horizontal pitch of smoke tubes, in mm;
d — diameter of tube holes, in mm.

2.7 The minimum pitch t of the smoke tubes secured in tube plate is to be determined by the following formula:

expanded tubes:

$$t = 1.125\,d + 12.5 \quad \text{mm}$$

welded tubes:

$t = 1.125d + 7$ mm for gas smoke temperature ≤ 800℃
$t = 1.125d + 9$ mm for gas smoke temperature > 800℃

where: d — outside diameter of smoke tubes, in mm.

2.8 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is not to be less than 1.75 times the thickness of plate, with a minimum of 38 mm.

Where tube plates or flat plates of combustion chambers are flanged for connection to the wrapper plates, the inside radius of flanging is not to be less than thickness of the plate, with a minimum of 25 mm.

3 *Point of support*

3.1 The points of support of boiler flat plates are to comply with the following:

(1) Long stays, short stays, stay tubes, welded-in smoke tubes (within the tube nests only) and flanges may be taken as points of support.

(2) Points of support of flanges:

① Where the inner radius of flange curvature does not exceed 2.5 times the thickness of the plate, the commencement of the flange curvature is to be taken as the point of support.

② Where the inner radius of flange curvature exceed 2.5 times the thickness of the plate, the point of support is to be taken at the position of 2.5 times the plate thickness measured from the inner surface of the flange.

(3) Where the furnace and front end plate are jointed by fillet welding, the outer surface of furnace is to be taken as a point of support.

(4) Where smoke tubes are fitted by means of roller expansion, the flanges of manholes or sight-holes are not to be taken as points of support.

3.2 Stay bars, stay tubes and welded-in smoke tubes, which are used as stays, are to be arranged as uniformly as possible to keep stayed areas as equal as practicable.

3.3 The area A supported by the stay is to be the area on the tube plate that is enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support. Such bisecting lines may approximately be taken as lines joining the center of a tangential circle for three or more adjacent points of support and the midpoint between two adjacent points of support, as shown in Figure 3.3. In respect to stay bars, stay tubes and plain smoke tubes, the stayed area is to be the above area less the area occupied by these stays, while the area occupied by diagonal stay bars are not to be deducted.

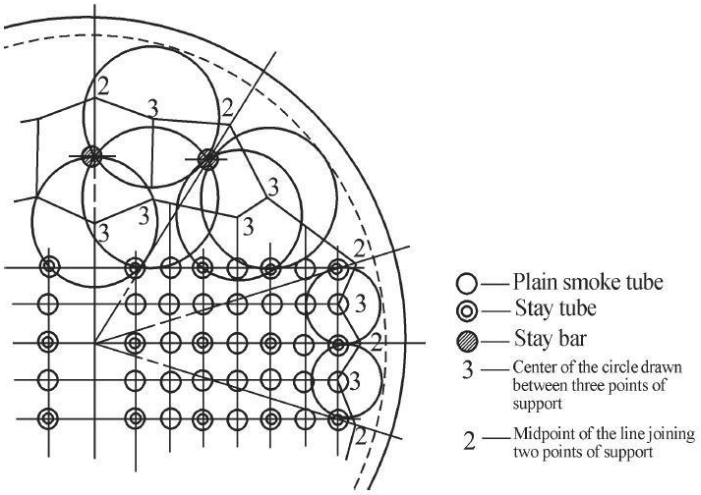


Figure 3.3

4 Plain smoke tubes

4.1 The minimum wall thickness δ of plain smoke tubes is to be determined by the following formula or is to be selected in accordance with Table 6.3.4.1, but in no case is to be less than 3 mm:

$$\delta = \frac{pd_1}{69} + 2 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

d_1 — outside diameter of smoke tubes, in mm.

Minimum wall thickness of smoke tubes *Table 4.1*

Outside diameter of tube, in mm	Wall thickness of tube, in mm				
	3	3.2	3.5	4.0	5.0
	Allowable design pressure, in MPa				
38	1.76				
44.5	1.52	1.81			
51	1.32	1.57	2.01		
57	1.18	1.42	1.77		
63.5	1.08	1.28	1.62	2.16	
70	0.98	1.18	1.47	1.96	
76	0.88	1.08	1.32	1.77	
83	0.78	0.98	1.23	1.62	
89		0.88	1.13	1.52	2.3

4.2 The smoke tubes may be fitted by means of roller expansion or by welding to the plates. Where the smoke tubes are fitted by welding, they are to be in compliance with Figure 4.2.

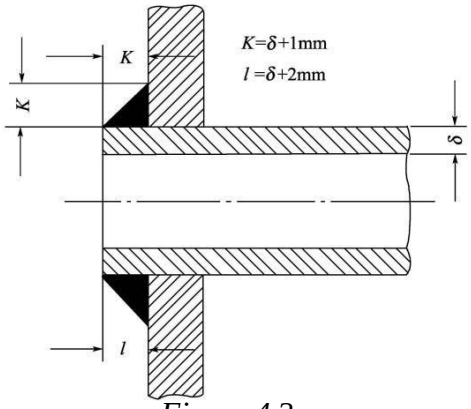


Figure 4.2

5 Stay tubes

5.1 The cross-sectional area F of welded-in stay tubes supporting tube plates is to be determined by the following formula, but in no case is the thickness of stay tubes to be less than 3.5 mm.

$$F = \frac{pA}{[\sigma]} \quad \text{mm}^2$$

where: p – design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

A – area of tube plate supported by one stay tube, in mm^2;

$[\sigma]$ – allowable stress, taken as 67 N/mm^2.

5.2 The stay tubes are to be welded to the tube plates in accordance with Figure 5.2(1) or (2).

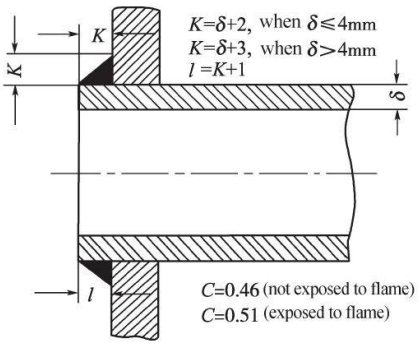


Figure 5.2(1)

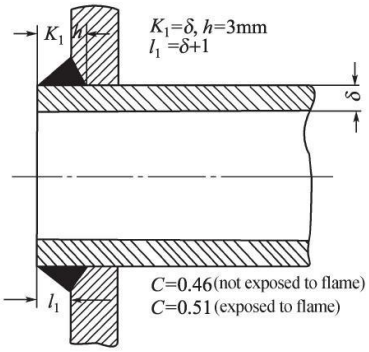


Figure 5.2(2)

6 Stays

6.1 The minimum cross-sectional area F of welded-in stays supporting the flat plates is to be determined by the following formula:

$$F = \frac{pA}{[\sigma]} \quad \text{mm}^2$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

A — maximum area of flat plate supported by one stay, in mm^2;

$[\sigma] = \frac{R_m}{5.3}$, in N/mm^2, for long stays;

R_m — specified tensile strength of materials, in N/mm^2;

$[\sigma]$ = 62, in N/mm^2, for short stays.

6.2 The structural details of welded-in stay bars are to comply with Figures 6.2. The structure shown in Figure 6.2(1) is to be used where the gas temperature is not over 600℃.

6.3 Where stay bars are connected to the flat tube plate and the shell as shown in Figure 6.3, the bar ends inserted into the flat tube plate are to be welded according to the requirements of 6.2. The minimum cross-sectional area F of the stay bar is to be calculated as follows:

$$F = \frac{pA}{[\sigma]\sin\alpha} \quad \text{mm}^2$$

where: α — angle between stay bar and flat tube plate, in degrees, not less than 60°.

Other symbols are the same as in 6.1.

6.4 In Figure 6.3, the throat thickness δ_h of the weld connecting stay bars and the shell is to comply with

$$\delta_h \geq \frac{1.25F}{2L_h} \quad \text{mm}$$

the following in respect to type I welds:

where: F— minimum cross-sectional area of stay bars, in mm^2;

L_h — weld length, in mm.

In any case, the throat thickness δ_h is not to be less than 10 mm.

For type II welds, the throat thickness δ_h is to be taken as d/4.

The weld length is to comply with the following formula:

$$L_h \geq \frac{2.50F}{d} \quad \text{mm}$$

where: F— minimum cross-sectional area of stay bars, in mm^2;

d— diameter of stay bars, in mm.

6.5 The diameter of stay bars is in general not to be less than 25 mm.

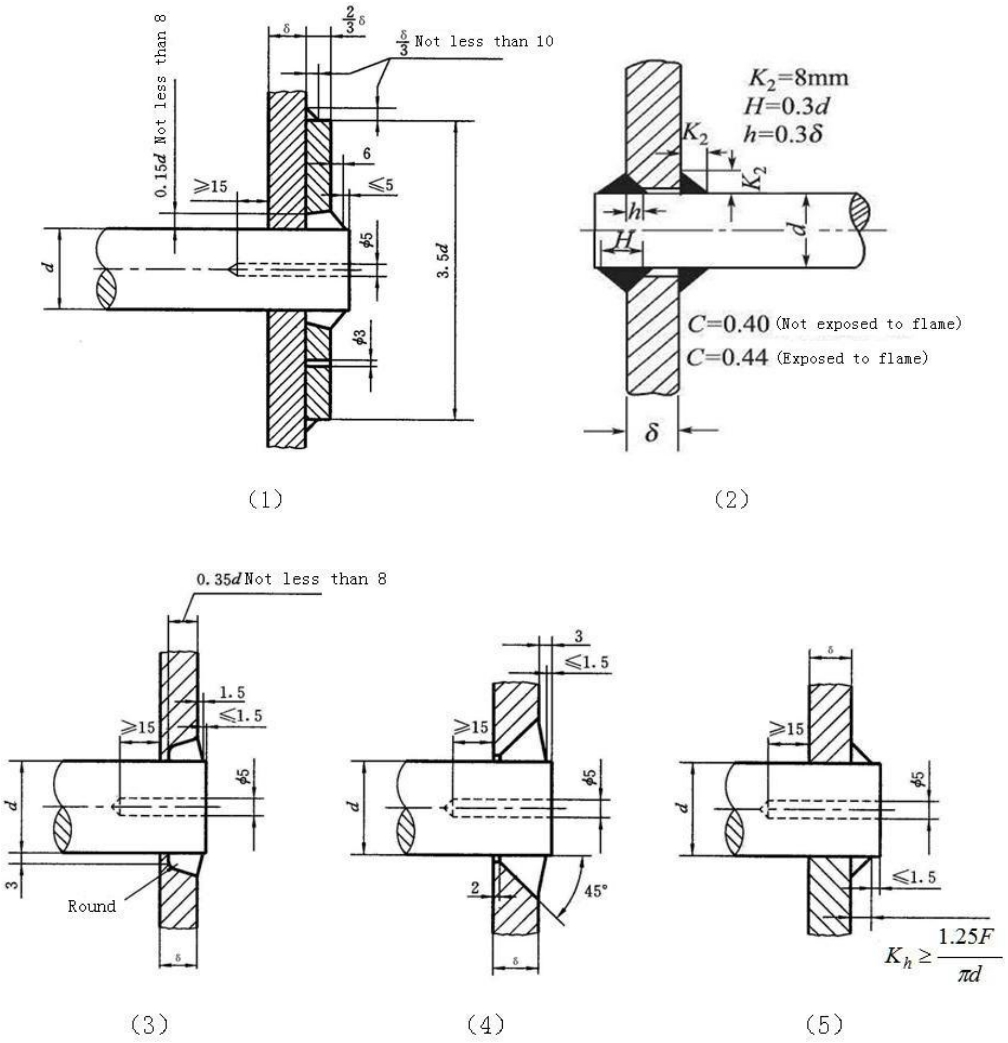


Figure 6.2

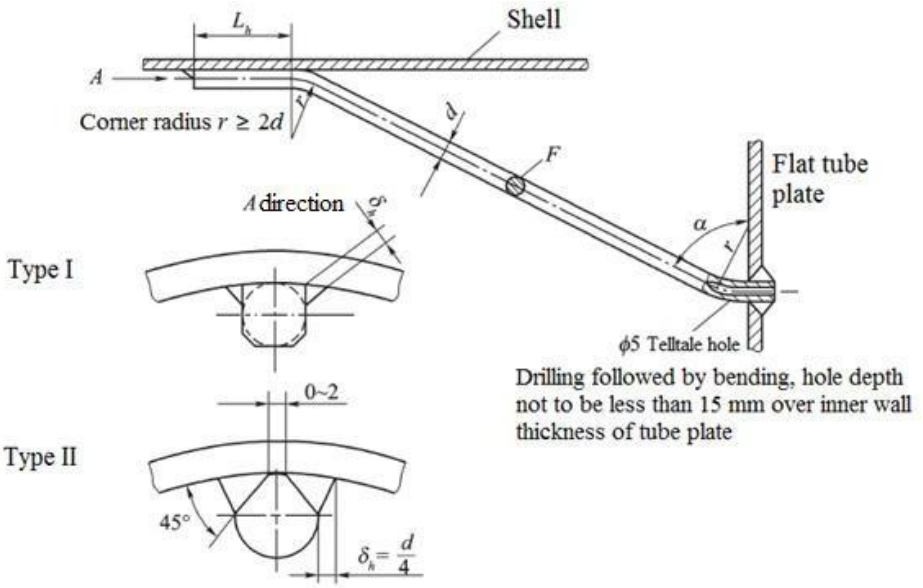


Figure 6.3

7 Furnaces

The minimum thickness δ of corrugated furnaces is to be determined by the following formula:

$$\delta = \frac{pD}{106} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — external diameter of the furnace measured at the bottom of the corrugations, in mm.

The minimum thickness δ of plain furnaces or of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, whichever is the greater:

(1) $$\delta = \sqrt{\frac{pD(L+610)}{10300}} + 0.75 \quad \text{mm}$$

(2) $$\delta = \frac{KpD + 0.34L}{110} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

L — maximum length between two points of support of the plain furnace, or for the cylindrical bottom of combustion chamber, in mm. The bisecting plane perpendicular to the axis of reinforcing ring, the commencement of flange curvature of rear tube plate and the fillet welded seam of the front tube plate are to be taken as the point of support for the measurement of the length for calculation of the furnaces;

D — external diameter of the plain furnace or twice the external radius of the cylindrical bottom of combustion chamber, in mm;

$$K = \frac{X}{[R_{eH}^T]}$$

X — specified minimum proof stress ($\sigma_{0.2}$), in N/mm^2, for carbon and carbon-manganese steel with a specified minimum tensile strength of 400 N/mm^2, at a temperature of 90°C above the saturated steam temperature corresponding to the design pressure;

$[R_{eH}^T]$ — specified minimum proof stress ($\sigma_{0.2}$), in N/mm^2, for the steel actually used, at a temperature of 90°C above the saturated steam temperature corresponding to the design pressure .

7.3 The thickness of both plain and corrugated furnaces is in no case to be less than 8 mm, nor greater than 22 mm.

7.4 Where the sections of the plain furnace are jointed by reinforcing rings, the calculated length of each section is in general not to exceed 1000 mm. The reinforcing ring may be of two halves welded together, with an inner radius of curvature R = (3 to 4) δ, and a length of straight portion l =2δ (see Figure 7.4).

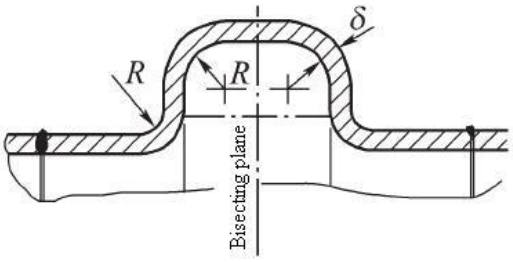


Figure 7.4

8 Crown plates and girders of combustion chambers

8.1 The crown plate and welded-on girders of combustion chambers (see Figure 8.1) are to comply with the following requirements:

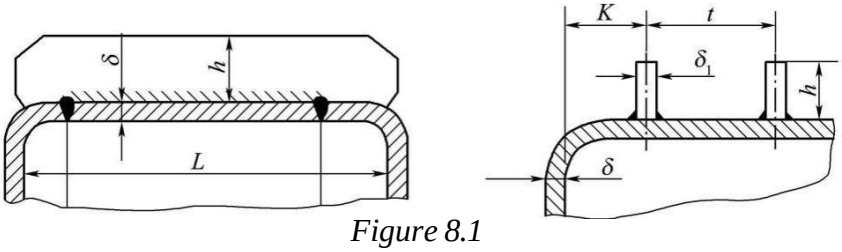


Figure 8.1

(1) The pitch t of the crown plate girders is in general not to be less than 10 δ, but not more than 25 δ.

(2) The thickness of girders δ_1 is not to be less than δ.

(3) The side girders are to be arranged at a distance K equal to or less than the pitch t from the commencement of curvature of the wrapper plates.
(4) The length of the girders is to be equal to the length of the combustion chamber L.
(5) Girders are to have semi-circular scallops above the welded seams of the crown plate, or to have the welds made flush.
(6) The crown plates of the wing combustion chambers are to be made inclined outward not less than 4°.
8.2 The minimum thickness δ of the crown plate of combustion chambers stiffened by welded-on girders is to be determined by the following formula:

$$\delta = 0.56t\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
t — pitch of girders, in mm;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.
8.3 The minimum depth (h) of welded-on girders on the crown plate of the combustion chambers is to be determined by the following formula:

$$h = \frac{L}{0.68}\sqrt{\frac{pt}{\delta_1 R_m}} \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
t — pitch of girders, in mm;
R_m — specified tensile strength of steel used for girders, in N/mm^2;
L — length at the top of combustion chamber measured internally from tube plate to back chamber plate, in mm;
δ_1 — thickness of girders, in mm.

Appendix 3 STRENGTH CALCULATION OF VERTICAL AUXILIARY BOILERS

1 *Cylindrical shell*

1.1 The thickness of the cylindrical shell of vertical auxiliary boilers is to be determined in accordance with 1.1 in Appendix 1 of this Chapter, but in no case is to be less than 5 mm.

2 *Dished end plates subject to internal pressure*

2.1 The minimum thickness of ellipsoidal, torispherical and hemispherical end plates without support subject to pressure on the concave side is to be determined in accordance with 5.1 in Appendix 1 of this Chapter. The construction and openings in dished end plates are to comply with the requirements of 5.2 and 5.3 in Appendix 1 of this Chapter.

2.2 The minimum thickness δ of torispherical end plates which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$\delta = \frac{pR}{1.3[\sigma]} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — inside radius of curvature of the end plate, in mm;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

3 *Flat crowns*

3.1 The minimum thickness δ of flat crown plates of boilers which are supported by central uptakes is to be determined by the following formula:

$$\delta = cd\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure of boiler, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

d — diameter of the largest circle drawn through two points of support by flanges, in mm;

c — constant:

c = 0.47, for plates not exposed to flame;

c = 0.51, for plates exposed to flame.

4 *Tube plates*

4.1 In addition to complying with the requirements of 2.2 to 2.6 in Appendix 2 of this Chapter, the minimum thickness of flat tube plates of vertical boilers having horizontal smoke tubes is to be determined by the following formula, whichever is the greater:

$$\delta = \frac{2pDt}{R_m(t-d)} + 0.75 \quad \text{mm}$$

where: p — design pressure of boiler, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — twice the radial distance measured from the centre of cylindrical shell to the centre of tubes holes in the outer row, in mm;

t — vertical pitch of tubes, in mm;

d — diameter of tube holes, in mm.

R_m — specified tensile strength of tube plate material, in N/mm^2.

5 *Horizontal shelves of tube plates*

5.1 For vertical boilers having horizontal smoke tubes, the horizontal shelves of the tube plates are to be supported by gussets as follows:

(1) For the combustion chamber tube plate (rear tube plate) the minimum number of gussets is to be:

1 gusset, when $255{,}000 < K \leq 350{,}000$;

2 gussets, when $350{,}000 < K \leq 420{,}000$;

3 gussets, when $K > 420{,}000$.

(2) For the smoke box tube plate (front tube plate) the minimum number of gussets is to be:

1 gusset when $250{,}000 < K \leq 470{,}000$;

2 gussets when $K > 470{,}000$.

Coefficient K is to be obtained from the following formula:

$$K = \frac{10.2ADp}{\delta}$$

where: A — maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm;

D — inside diameter of the boiler shell, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

δ — thickness of tube plates, in mm.

5.2 The shell plates to which the sides of the tube plates are connected are to be 1.6 mm thicker than that required in the formula applicable to shell plates. Where gussets are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4.5 related to the specified minimum tensile strength of the shell plate material.

5.3 The minimum thickness δ of the vertical furnace or internal uptake of the vertical boiler is to be determined by the following two formulae, whichever is the greater:

(1) $$\delta = \sqrt{\frac{pD(L+610)}{10300}} + C \quad \text{mm}$$

(2) $$\delta = \frac{KpD + 0.34L}{110} + C \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — external diameter of the cylindrical furnace or internal uptake, in mm. Where the furnace is tapered, the diameter D is to be taken at the middle point of the calculated length L of the furnace;

L — calculated length of the cylindrical furnace or internal uptake, in mm, i.e. the length between two points of substantial support (see Figure 5.3, where H is the height of dished end). The symbol D is the same as above and Y is to be taken in accordance with Table 5.3. Where the furnace is supported by a circumferential row of regularly arranged stays with a diameter not less than 2.25 δ, and a pitch not exceeding 14 δ, these stays may be regarded as a point of support of calculated length;

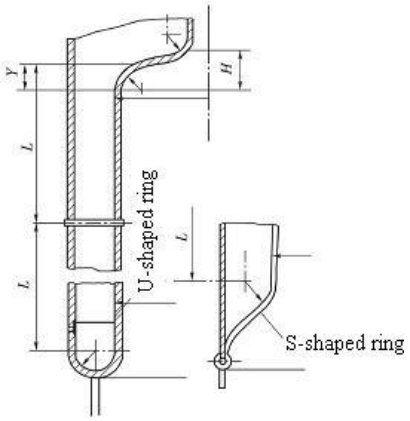


Figure 5.3

Value of *Y* **Table 5.3**

H/D	0.169	0.2	0.25	0.3	0.4	0.5
Y/D	0.07	0.08	0.10	0.12	0.16	0.20

Note: *Y/D* between two adjacent values is determined by means of arithmetic interpolation.

C — allowance:

C = 2 mm for furnace;

C = 4 mm for internal uptake;

$$K = \frac{X}{[R_{eH}^T]}$$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

6 *Hemispherical furnaces*

6.1 The minimum thickness δ of unsupported hemispherical furnaces subject to pressure on the convex side is to be determined by the following formula:

$$\delta = \frac{KpR}{61} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the furnace, in mm;

$K = \frac{X}{[R_{eH}^T]}$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

7 Torispherical furnaces subject to pressure on the convex side

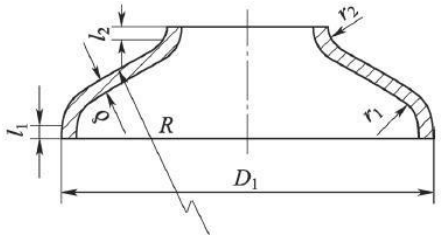
7.1 The minimum thickness δ of vertical furnace end plates which are subject to pressure on the convex side and are supported by central uptakes (see Figure 7.1 of this Appendix) is to be determined by the following formula:

$$\delta = \frac{pR}{[\sigma]} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the end plates, in mm;

$[\frac{1}{10}]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.



$R < D_1$;
$r_1 > 4\ \delta$, and > 50 mm;
$r_2 > 2\ \delta$, and > 25 mm;
l_1 and l_2, butt welding structure > 2 δ

Figure 7.1

The minimum thickness δ of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays, is to be determined by the following formula, but is in no case to be less than the thickness determined by 5.3 of this Appendix:

$$\delta = \frac{KpR}{66} + 0.75 \quad \text{mm}$$

where: δ— the minimum thickness of flanged ends for boiler furnaces, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the end plates, in mm;

$K = \frac{X}{[R_{eH}^T]}$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

7 *Ogee rings*

7.1 The minimum thickness δ of the ogee ring which connects the bottom of the furnace to the boiler shell and sustains the whole vertical load on the furnace (see Figure 8.1) is to be determined by the following formula:

$$\delta = \sqrt{\frac{pD(D-d)}{990}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — internal diameter of boiler shell, in mm;

d — outside diameter of the furnace where it connects the ogee ring, in mm.

7.2 The minimum thickness of the U-shaped ring as shown in Figure 8.2 is to be 20% thicker than that obtained from the formula as specified 8.1 of this Appendix.

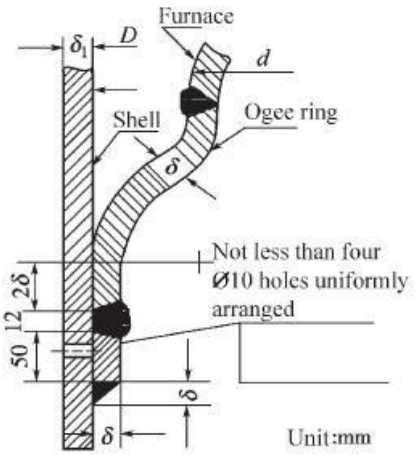


Figure 8.1

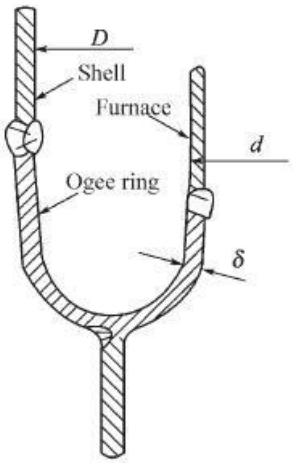


Figure 8.2

Appendix 4 STRENGTH CALCULATION OF PRESSURE VESSELS

1 Strength calculation

1.1 The strength calculation of pressure vessels is to comply with the strength calculation of relevant structure for water tube boilers, contained in Appendix 1 of this Chapter; however, the allowable stresses used in the calculation are to be determined in accordance with 6.2.5.1 of this Chapter. Where an accumulator works at frequently fluctuating working pressure, the allowable stress for its parts is to be appropriately lowered according to the fluctuation condition of pressure.

1.2 For the design pressure and allowable stress of pressure vessels, see 6.1.3.1(1) and 6.2.5.1 of this Chapter.

1.3 The minimum thickness δ of cylindrical shell of the pressure vessels is in no case to be less than that determined by the following formula:

$$\delta \geq 3 + \frac{D_0}{1500} \quad \text{mm}$$

where: D_0 — inside diameter of pressure vessels, in mm.

Appendix 5 OPENINGS AND COMPENSATION

1 *Cylindrical shells*

1.1 Any openings in cylindrical shells, including manholes, hand-holes, openings for standpipes or connecting branches and tube holes, having diameters exceeding those obtained from the formula in 1.2 of this Appendix, are to be reinforced in accordance with the requirements as specified in 1.3 of this Appendix.

1.2 The maximum diameter d of any unreinforced openings is to be determined by the following formula, but in no case is to exceed 200 mm:

$$d = 8.1 \sqrt[3]{D_1\delta(1-K)} \quad \text{mm}$$

where: δ— actual thickness of cylindrical shell, in mm;

D_1— outside diameter of cylindrical shell, in mm;

$K = \dfrac{pD_1}{1.82[\sigma]\delta}$, but not more than 0.99

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

For elliptical holes arranged with their major axes in longitudinal direction, the major axes are to be taken as the diameter of the opening; for elliptical holes arranged with their minor axes in longitudinal direction, the mean of the major and minor axes are to be taken as the diameter of the openings.

1.3 Openings in cylindrical shells larger than those permitted by 1.2 of this Appendix are to be reinforced by the methods shown in the following Figures:

Figure 1.3(1): Reinforcement by stand-pipe or compensating ring;

Figure 1.3(2): Reinforcement by compensating plate; and

Figure 1.3(3): Combined reinforcement by standpipe or compensating ring together with compensating plate. Reinforcement will be considered adequate when the effective compensating sectional area is equal to or more than the sectional area in way of the openings.

(1) Half the effective compensating sectional area, shown in Figures 1.3(1) to (3) of this Appendix, is to be taken respectively as the total of the following relevant sectional areas:

① Surplus thickness of cylindrical shell multiplied by effective width, i.e. $A_1 = (\delta - \delta_0)\, B$ mm^2;

② Thickness of compensating plate multiplied by effective width, i.e. $A_2 = \delta_2 B$ mm^2;

③ Surplus thickness of standpipe or compensating ring multiplied by effective height, i.e. $A_3 = (\delta_1 - \delta_3)\, h_1$ mm^2;

④ Sectional area of that portion of the standpipe or compensating ring which projects inside the shell, i.e. $A_4 = \delta_1 \times h_2$ mm^2.

(2) Half the sectional area requiring compensating in way of the opening, i.e.:

$$\frac{d_1}{2} \times \delta_0 \quad \text{mm}^2.$$

(3) The symbols used in (1) and (2) above are defined as follows:

δ — actual thickness of the shell, in mm;

δ_0 — thickness, in mm, to be determined in accordance with 1.1 in Appendix 1 of this Chapter, where the strength factor φ of the shell is equal to 1;

δ_1 — actual thickness of standpipes or compensating rings, in mm;

δ_2 — thickness of compensating plates, in mm;

δ_3 — thickness of standpipes, as determined by 9.1 in Appendix 1 of this Chapter, in mm;

d_1 — inside diameter of standpipes or compensating rings;

B = $\sqrt{D_0\delta}$, but not more than $0.5d_1$, in mm;

h_1 = $0.8\sqrt{d_1\delta_1}$, in mm;

h_2 — effective height above the inner side of the shell, in mm, taken as the actual one, but not greater than h_1;

D_0 — inside diameter of cylindrical shell, in mm.

(4) Where the material for the standpipe, compensating ring or compensating plate has an allowable stress lower than that of the shell, the effective compensating sectional area as prescribed in (1) above is to be corrected by multiplying the ratio of allowable stress of standpipe, compensating ring or compensating plate and the allowable stress of shell.

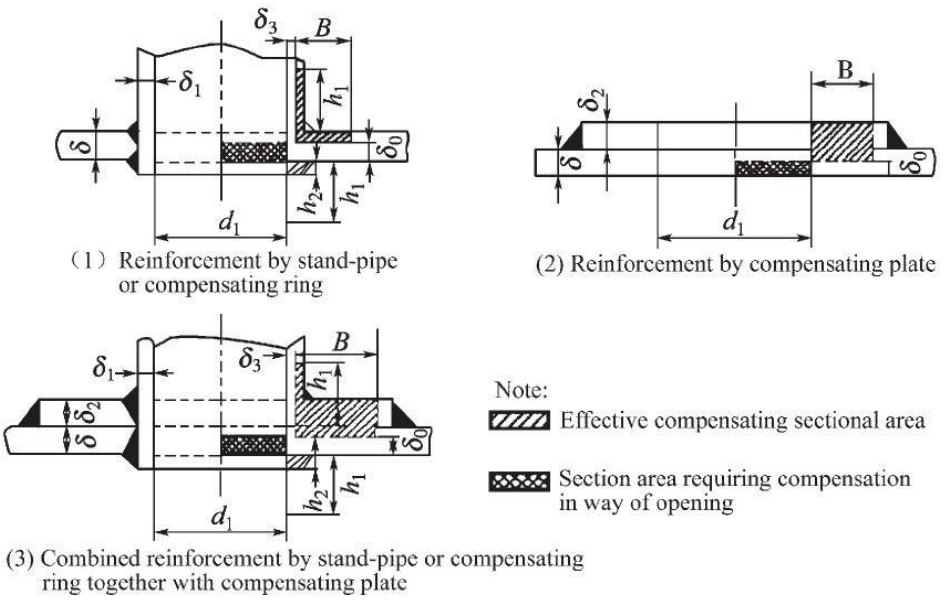


Figure 1.3

2 Dished end plates

2.1 For openings with effective reinforcement in dished end plates, the opening factor $d/\sqrt{D_1\delta}$ is to be calculated as described in 5.1 in Appendix 1 of this Chapter, but d in the formula is to be replaced by the equivalent diameter d' of openings, which is determined by the following formula:

$$d' = d - \frac{A}{\delta} \qquad \text{mm}$$

where: d — actual diameter of opening in dished end plate, in mm;

A — sectional area of the effective reinforcement, in mm^2, to be determined in accordance with 2.2 of this Appendix. The reinforcement is to be so arranged that the distance from its outer edge to the outside edge of dished end plate is not less than $0.1D$; the reinforcement is to be welded on the dished end plate in accordance with 2.3 of this Appendix.

2.2 Openings in dished end plates may be reinforced with standpipe, compensating ring or compensating plate, or with compensating ring combined with compensating plate, see Figure 2.2(1) of this Appendix. The effective compensating sectional area A is to be taken as the total of the following sectional area:

(1) thickness of compensating plate multiplied by effective width, in mm^2, i.e. $A_1 = 2\delta_2 B$ mm^2;

(2) surplus thickness of standpipe or compensating ring multiplied by effective height, i.e. $A_2 = 2\,(\delta_1 - \delta_3)h_1$ mm^2;

(3) thickness of standpipes or compensating ring multiplied by effective height of that portion of standpipe or compensating ring which projects inside the end, i.e. $A_3 = 2\,h_2\delta_1$ mm^2.

where: B — effective width, $B \le \sqrt{2R\delta}$ or $B \le 0.5d$, in mm, the smaller value being taken;

R — inside radius of the spherical portion of the torispherical end, or inside radius of the meridian of the ellipse at the center of the opening for ellipsoidal end, in mm, to be determined by the following formula:

$$R = \frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b} \qquad \text{mm}$$

where: a, b and x are shown in Figure 2.2(2) of this Appendix;

h_1 — effective height, $h_1 = l + \delta + \delta_2$, in mm;

h_2 — effective height, $h_2 = l = \sqrt{d \cdot \delta_1}$, in mm;

δ — thickness of dished end plate, in mm;

δ_1 — thickness of standpipe or compensating ring, in mm;

δ_2 — thickness of compensating plate, in mm;

δ_3 — minimum thickness as required in 1.1 in Appendix 1 of this Chapter, in mm.

Where the reinforcement material for openings in dished end plates has an allowable stress lower than that of the end plate, the effective sectional area of compensating material is to be corrected by multiplying the ratio of allowable stress of compensating material and allowable stress of dished end plate.

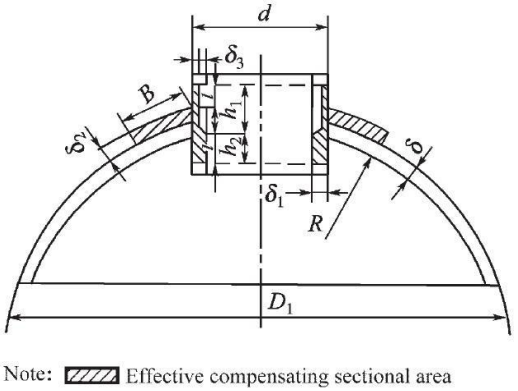


Figure 2.2(1)

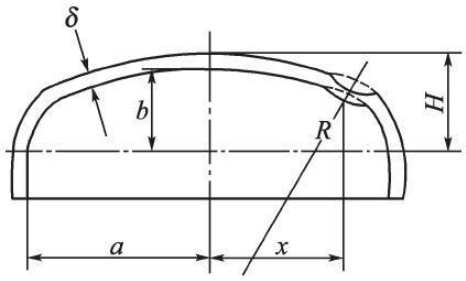


Figure 2.2(2)

2.3 Acceptable welded construction methods for compensating the openings are as shown in Figure 2.3 of this Appendix. Alternative methods of attachment by welding may be accepted provided that equivalent strength of welding is obtained.

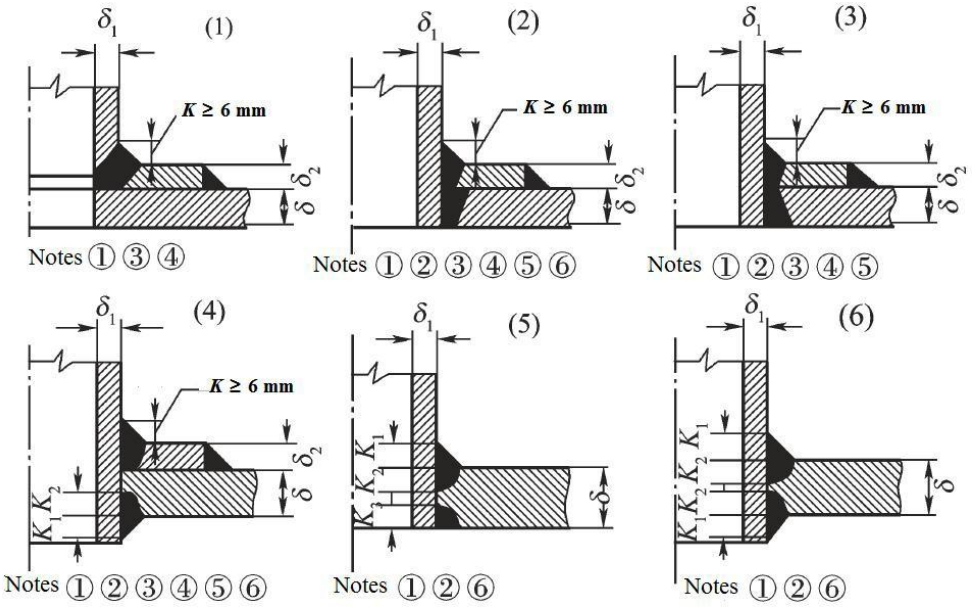


Figure 2.3

Notes:

① Where the thickness of standpipes or compensating rings is less than or equal to 10 mm, the ratio of $\delta_1/\delta$is in general not to be less than 1/5.

② There is to be a clearance between the inside of holes and outside of standpipes or compensating rings. This clearance is not to be more than 3 mm or $\delta_1/2$, whichever is the smaller.

③ There is to be no clearance between compensating plate and the shell plate.

④ Root of welds is to be gouged and a back sealing run is to be applied; where full penetration of welds can be ensured, the back sealing run may be dispensed with.

⑤ Care is to be taken that the welding stress is to be minimized as far as possible during welding.

⑥ Weld sizes:

$K \geq 6$ mm;

$K_1 + K_2 = 1.5\delta_1$, but K_1 is not to be more than 14 mm or $\delta_1/2$, whichever is lesser;

$K_3 = \delta_1$.

3 *Furnaces*

3.1 Calculations for the reinforcement of furnace openings are to be in accordance with the relevant requirements of Appendix 1.

3.2 In calculating the reinforcement of furnace openings, the furnace thickness is to be assumed as being determined according to 1.1 of Appendix 1, and the strength factor of the shell taken as $\varphi = 1$.

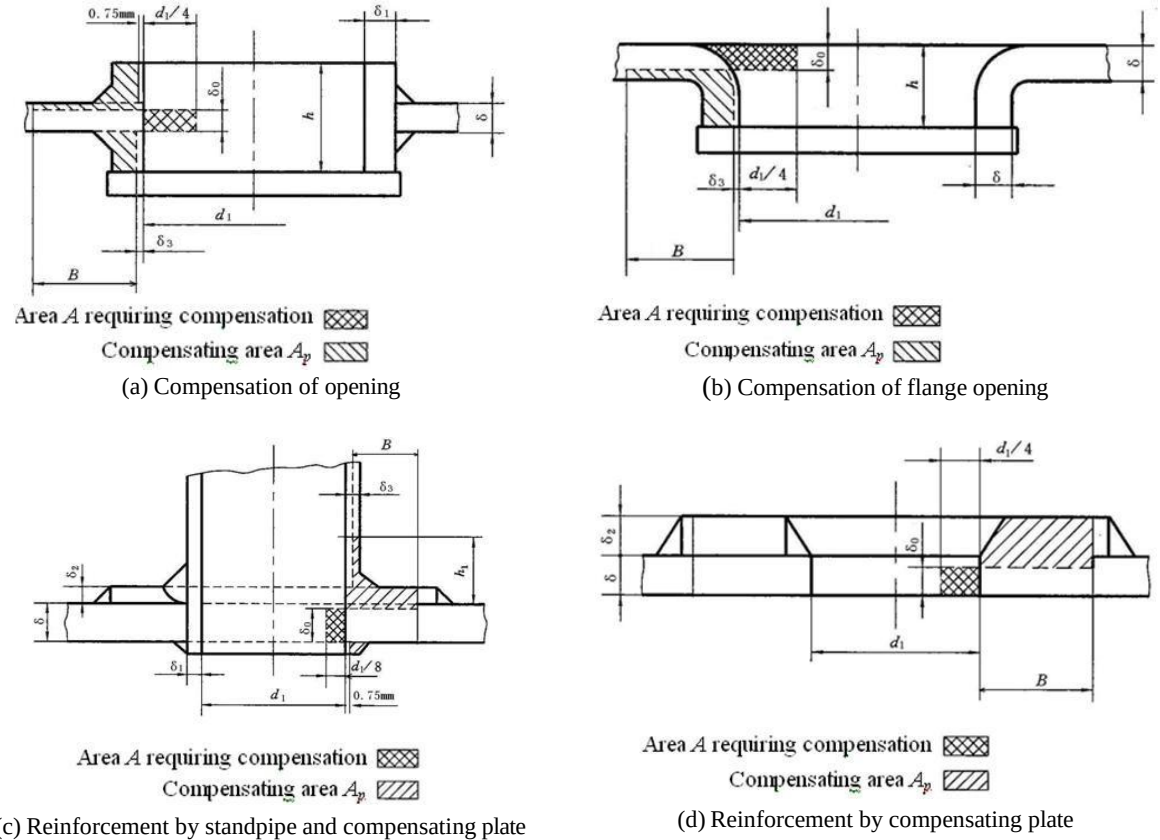
3.3 Furnace openings are not to be reinforced by compensating plates.

4 *Flat plates*

4.1 Where the actual thickness of flat plates complies with the following formula, no compensation of openings is necessary:

$$\delta \geq K_1 \delta_0 \quad \text{mm}$$

where: K_1 = 1.5 (Figure 4.1(a), (b) and (d));
K_1 = 1.25 (Figure 4.1(c)).



(a) Compensation of opening

(b) Compensation of flange opening

(c) Reinforcement by standpipe and compensating plate

(d) Reinforcement by compensating plate

Figure 4.1

Symbols in Figure 4.1:

δ — actual thickness of flat plate, in mm;
δ_0 — minimum thickness of flat plate, in mm, obtained according to the relevant requirements in Appendixes 1 and 2 of this Chapter;
δ_1 — actual thickness of standpipe or reinforcing ring, in mm;
δ_2 — thickness of compensating plate, in mm;
δ_3 — thickness of standpipe, in mm, obtained according to 9.1, Appendix 1 of this Chapter;
d_1 — inner diameter of opening, standpipe or opening ring, in mm;
A — effective breadth of compensation, taken as $0.5d_1$, in mm;
h_1 — effective height of compensation, taken as the lesser of $2.5\delta_1$ and 2.5δ, in mm;
h — height of welded ring or flange height of flange opening, in mm.

4.2 Where the requirements of 4.1 are not complied with, the openings of flat plates are to be reinforced.

4.3 The effective cross-sectional area A_p of compensation and the cross-sectional area A requiring compensation, as shown in Figure 4.1, are to comply with the following formula:

$$A_P \geq A$$

4.4 In (a) and (b) of Figure 4.1, the height of welded ring or the flange height of flange opening is to comply with the following formula:

$$h \geq \sqrt{\delta d_1} \quad \text{mm}$$

In the case of an elliptical opening, the inner diameter d_1 of the opening or opening ring is to be the size of the shorter axis of the ellipse.

Appendix 6 STRENGTH CALCULATION OF STANDPIPES, DOORS FOR MANHOLES AND SIGHT HOLES

1 Standpipes

1.1 The minimum wall thickness δ of standpipes welded direct to the boilers and pressure vessels is not to be less than that determined by 9.1 in Appendix 1 of this Chapter, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is not to be less than:

$$\delta = 0.015D + 3.2 \quad \text{mm}$$

where: D — outside diameter of the standpipes, in mm.

1.2 In general, the wall thickness of the standpipes need not exceed that of the shell.
Where a standpipe is connected by screwing, the thickness is to be measured at the root of the thread.

2 Doors for manholes and sight holes

2.1 Doors for manholes and sight holes are to have sufficient strength, and the minimum thickness δ of which is to be determined by the following formula:

$$\delta = 0.8\, ab \sqrt{\frac{p}{(a^2 + b^2)[\sigma]}} + 0.75 \quad \text{mm}$$

where: a — length of major axis of the door, in mm, measured from the centre of jointing surface;
b — length of minor axis of the door, in mm, measured from the certre of jointing surface;
p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

CHAPTER 7 STEAM TURBINES

Section 1 GENERAL PROVISIONS

7.1.1 *Application*

7.1.1.1 The requirements of this Chapter are applicable to steam turbines for main propulsion and to those for essential auxiliary services.

7.1.1.2 The certification requirements and product survey of steam turbines included in 7.1.1.1 of this Section are to comply with the requirements of Chapter 3, PART ONE of the Rules.

7.1.2 *Critical speed*

7.1.2.1 The steam turbines are to be so designed as to ensure freedom from critical speeds within the operating speed range.

7.1.3 *Astern turbines*

7.1.3.1 Main Propulsion turbines are to be installed with astern turbines or incorporated with reversing gears, and the astern power and astern speed are to comply with the relevant requirements in 1.2.4 of this PART.

7.1.4 *Plans and documents*

7.1.4.1 The following plans and documents are to be submitted for approval:

(1) General arrangement;

(2) Section of high-pressure and low-pressure cylinders;

(3) Rotor and shaft bearings;

(4) Nozzles and diaphragms;

(5) Moving blades;

(6) Quill shaft and couplings;

(7) Arrangement of steam turbine pipings (including steam, lub-oil and condensation water piping and indicating the material, size and rated working pressure of pipes);

(8) Technical performance of materials for principal component parts;

(9) Strength calculations for principal component parts;

(10) Welding specifications for principal component parts;

(11) Other plans and documents as deemed necessary by ISC.

7.1.4.2 The following plans and documents are to be submitted for information:

(1) Assembly sectional view of steam turbines;

(2) Specifications of steam turbines.

Section 2 MATERIALS

Testing of materials

The following parts are subject to testing in accordance with the relevant requirements for materials in ISC Rules for Materials and Welding:

(1) rotating parts such as rotors, discs, shafts, shrink rings, blades, toothed couplings and other dynamically loaded components as well as valve spindles and cones;

(2) stationary parts such as casings, diaphragms, nozzles and nozzle boxes, guide vanes, turbine casing bolts, bed frames and bearing seats;

(3) pipes and pipe plates of condenser.

For small auxiliary turbines with inlet steam temperature of 250℃ and below, the test of the material is to be limited only for the material of the blades and shafts.

Non-destructive test

Magnetic particle or liquid penetrant tests are required for rotating parts (including turbine rotor shafts, stiff and flexible couplings, bolts for couplings, blades (sample), gears and other dynamically stressed parts), and at the same time, ultrasonic examination is to be carried out to rotor shafts.

Magnetic particle or liquid penetrant tests are required for stationary parts (including castings and plates for casings) and the spots are to be agreed between the manufacturer and the surveyor.

Non-destructive tests to piping and associated fittings are to comply with the relevant requirements in Chapter 2 of this PART.

Section 3 DESIGN

7.3.1 *Construction of rotors*

7.3.1.1 Smooth fillets are to be provided at abrupt changes of section of blade roots, discs, rotors and bosses. Sharp edges of keyways and balancing holes are to be well rounded.

7.3.1.2 Any two among the wheel blade filling piece, balancing hole and keyway of a disc are not to be arranged on the same radial direction. Where the discs are shrunk on the rotor, the angle subtended between the keyways of any two adjacent discs is not to be less than 90°.

7.3.1.3 Under any working conditions, appropriate radial and axial clearances are to be provided between the moving parts and stationary parts, as well as in the gland sealing of turbines.

7.3.1.4 For propulsion turbines having astern stages, blades are to have sufficient strength to withstand the increased load arising from the counter-steam during reversing.

7.3.1.5 The vibration adjustment for the blading of prototype turbine is to be carried out so as to avoid resonance under service conditions and ensure safe running at any rating.

7.3.2 *Construction of stators*

7.3.2.1 Adequate provision is to be made for the relative thermal expansion of cylinders, diaphragms and nozzle boxes.

7.3.2.2 For the astern turbine, the built-in nozzle box or built-in casing is to be so arranged as to ensure the possibility of free axial or radial expansion relative to the turbine casing. The steam inlet pipe of the astern turbine is not to be rigidly connected to the casing.

7.3.2.3 Where carbon rings are used for outer gland sealing, they are to be capable of being repaired or renewed without opening the casing.

7.3.2.4 Turbine casings are to be provided with suitable drain devices.

7.3.3 *Bearings*

7.3.3.1 The journal bearings and thrust bearings of steam turbines are to be of plain type.

7.3.3.2 It is recommended that self-aligning types be adopted for both journal bearings and thrust bearings of propulsion turbines with high initial steam pressure and turbines designed for quick starting from cold condition. Alternatively, thrust bearings may be of such construction as to ensure uniform distribution of the thrust on the pads.

7.3.3.3 The oil well of the bearing seats is to be so constructed as to ensure that the lubricating oil system is capable of working free from troubles when the ship is under trim or list conditions as specified in 1.2.1.1 of this PART. The temperature of the bearing lubricating oil is not to exceed 70℃.

7.3.4 *Piping*

7.3.4.1 The design of steam piping is to comply with the relevant requirements in Section 3, Chapter 4 of this PART.

7.3.4.2 The design of lubricating oil piping is to comply with the relevant requirements in Section 6, Chapter 4 of this PART.

7.3.4.3 The design of cooling water piping is to comply with the relevant requirements in Section 5, Chapter 4 of this PART.

Section 4 FITTINGS

7.4.1 Overspeed protective devices

7.4.1.1 An overspeed protective device is to be provided for main and auxiliary turbines so as to shut off the steam supply automatically when the turbine speed exceeds 115% of the rated speed.

7.4.1.2 Where two or more turbines are coupled to the same gear wheel set, only one overspeed protective device may be provided for all the turbines.

7.4.1.3 Where exhaust steam from auxiliary systems is led to the main turbine, it is to be cut off at activation of the overspeed protective device.

7.4.1.4 Arrangement is to be provided for shutting off the steam to the main turbines by suitable hand trip

gear situated at the manoeuvring stand and at the turbine itself. Hand tripping for auxiliary turbines is to be arranged in the vicinity of the turbine overspeed protective device (The hand trip gear means any devices by hand manoeuvring, neglecting the executive action i.e. either by mechanical means or by external power means).

7.4.2 Low pressure protective devices for lubricating oil

7.4.2.1 Main ahead turbines are to be provided with a quick acting device which will automatically shut off the steam supply in the case of dangerous lowering of oil pressure in the bearing lubricating system. This device is to be so arranged as not to prevent the admission of steam to the astern turbine for braking purposes.

Where deemed necessary, appropriate means are to be provided to protect the turbines in case of:

(1) abnormal axial rotor displacement (see 7.4.4 Protective devices for axial displacement);

(2) excessive condenser pressure;

(3) high condensate level.

7.4.2.2 Auxiliary turbines having governors operated other than hydraulically in which the lubricating oil is inherent in the system, are to be provided with an alarm device and a means of shutting off the steam supply in the case of lowering of oil pressure in the bearing lubricating oil system.

7.4.2.3 Main steam turbines are to fitted with a satisfactory emergency supply of lubricating oil which will come into use automatically when the pressure drops below a predetermined value. Suitable arrangement for cooling the bearings after stopping is to be required. For emergency supply system of oil, see 4.6.3 of this PART.

7.4.3 Speed governors

7.4.3.1 Turbines for propulsion generators and auxiliary turbines intended for driving electric generators are to be provided with reliable governors.

7.4.3.2 The governor of a turbine installation incorporating electric transmission, controllable pitch propeller or reverse gear is to be capable of controlling the speed under various working conditions, without bringing the automatic overspeed protective device into action when full load is suddenly taken off.

7.4.3.3 The governors of auxiliary turbines intended for driving electric generators, in addition to the relevant requirements contained in Section 2, Chapter 3 of PART FOUR of the Rules, are to comply with the following:

Momentary variation is not to exceed 10% of the rated speed and permanent variation not to exceed 5% of the rated speed when full load is suddenly taken off.

Momentary variation is not to exceed 10% of the rated speed and permanent variation not to exceed 5% of the rated speed when 50% of the rated load of the generator is suddenly put on from no-load condition, followed by the remaining 50% load after an interval sufficient to restore the speed to steady state. The recovery time for the engine speed (i.e. the time for speed fluctuation ratio to return to ±1%) is not to exceed 5 s.

7.4.4 Protective devices for axial displacement

7.4.4.1 All propulsion turbines are to be equipped with devices indicating the axial position of the rotor relative to the stator.

7.4.4.2 A protective device is to be provided for main turbines so as to shut off the steam automatically when axial displacement of the turbine rotor is in excess of the specified value.

7.4.5 Gland sealing and condensate systems

7.4.5.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensate entering the turbines. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water can not impinge on the rotor or casing.

7.4.6 Safety devices for manoeuvring

7.4.6.1 Screw-down non-return valves or other approved means are to be fitted in steam bleeding-off pipes to prevent any steam and water from returning to the turbines.

7.4.6.2 Propulsion turbines are to be provided with power-driven turning gear. An interlock device is to be provided between turbine and turning gear to prevent the turbine from being started until the turning gear is disengaged.

7.4.6.3 An interlock device is to be provided for the ahead and astern manoeuvring valves of propulsion

turbines. A screw-down valve is also required between those valves.

7.4.6.4 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

7.4.7 Alarm devices

7.4.7.1 Propulsion turbines are to be fitted with alarm devices giving both audible and visible warnings when the vacuum in the condenser is lower than the specified value.

7.4.7.2 To provide a warning to personnel in the vicinity of the exhaust end steam turbines of excessive pressure, a sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary. When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to exhaust valve are designed, means to relieve the excess pressure are to be provided.

7.4.8 Emergency arrangements

7.4.8.1 In single screw ships fitted with cross compound steam turbines, the arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose, the steam may be led directly to the L.P. turbine and either the H.P. or M.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

7.4.8.2 The necessary pipes and valves for these arrangements are to be readily available and properly marked. A fit up test of all combination of pipes and valves is to be performed prior to the first sea trials.

7.4.8.3 The permissible power/speeds when operating without one of the turbines (all combinations) is to be specified and information provided on board.

7.4.8.4 The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

Section 5 TESTS AND TRIALS

7.5.1 *General requirements*

7.5.1.1 Turbines covered in 7.1.1.1 of this Chapter are to be subject to following tests and surveys.

7.5.2 *Material test and non-destructive test*

7.5.2.1 All components of turbines are to be subject to material test and non-destructive test according to the relevant requirements of 7.2.1 and 7.2.2 of this Chapter in the presence of the Surveyor.

7.5.3 *Test pressure*

7.5.3.1 All components of turbines together with associated equipment are to be tested to the hydraulic pressures as given in Table 7.5.3.1.

Hydraulic test pressure *Table 7.5.3.1*

Name	Test pressure (MPa)
Cylinder, steam receiver, nozzle box	1.5 p, but not less than 0.2
Operating valve	2 p
Steam jacket space of condenser	0.1
Cooling water jacket space of condenser	1.5 p

Note: p – working pressure, in MPa.

7.5.4 *Thermal stability test of rotors*

7.5.4.1 Where the inlet steam temperature exceeds 400 ℃ , the solid forged rotors or welded rotors of propulsion turbines are to be subject to a thermal stability test after heat treatment and rough machining of the forging.

7.5.5 *Dynamical balance test of rotors*

7.5.5.1 Rotors together with the half-coupling are to be dynamically balanced on completion of final assembly.

7.5.6 *Maximum load test of diaphragm*

7.5.6.1 All diaphragms of the first turbine of the same type are to be subject to a maximum load test for

checking their deflections.

7.5.7 *Safety relief valve test*

7.5.7.1 Safety relief valves required by Section 4 of this Chapter are to be subject to opening and closing test according to the design pressure of manufacturer.

7.5.8 *Workshop trials*

7.5.8.1 Upon completion of fabrication and assembly, each steam turbine is to be subject to a shop trial in accordance with manufacturer's test schedule, which is to be submitted for review before the trial.

7.5.8.2 The test schedule is to specify the duration of tests and to include full load test, half load response test, etc.

7.5.8.3 The overspeed protective device is to be tested.

7.5.9 *Shipboard trials*

7.5.9.1 After installation on board, each steam turbine, including all control and safety systems, is to be operated to satisfactorily demonstrate its function.

7.5.9.2 Freedom of steam turbine from harmful vibration at speeds within the operating range is to be demonstrated.

7.5.9.3 The reversing characteristics of propulsion turbine plants are to be demonstrated.

7.5.9.4 The function of governor is to be demonstrated.

CHAPTER 8 GAS TURBINES

Section 1 GENERAL PROVISIONS

8.1.1 *Application*

8.1.1.1 This Chapter applies to gas turbines for main propulsion and to those for essential and auxiliary services.

8.1.1.2 The certification requirements and product survey of gas turbines included in 8.1.1.1 of this Section are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

8.1.2 *Rating*

8.1.2.1 The rated output is defined as the maximum continuous power developed by gas turbines for continuous running under the following reference conditions:

(1) air at compressor inlet:

① temperature of 15℃;

② absolute pressure of 101.325 kPa;

③ relative humidity of 60%.

(2) cooling water inlet temperature is of 15℃(if applicable);

(3) static pressure of the exhaust in way of turbine exhaust flange (or heat recuperator outlet) is of 101.325 kPa.

The rated speed is defined as the speed corresponding to the rated output.

8.1.3 *Correction curves*

8.1.3.1 Correction curves are to be submitted by the manufacturers indicating the variation in major performance of gas turbines relating to ambient conditions.

8.1.4 *Astern running*

8.1.4.1 The astern power of the main propulsion gas turbines is to comply with the requirements of 1.2.4 of this PART.

8.1.5 *Miscellaneous*

8.1.5.1 The construction and arrangement of the components and systems of gas turbines are to be in compliance with the provisions as specified in 1.2.1.1 of this PART.

8.1.5.2 The welding of gas turbine components is to comply with the relevant provisions as specified in ISC Rules for Materials and Welding.

8.1.5.3 Automation systems of gas turbines are to comply with the relevant provisions as specified in PART SEVEN of the Rules.

8.1.5.4 Lubricating oil systems of gas turbines are to comply with the relevant provisions of Section 6, Chapter 4 of this PART.

8.1.6 *Plans and documents*

8.1.6.1 The following plans and documents are to be submitted for approval:

(1) Sectional assembly of gas turbines and compressors;

(2) Rotors, including blades;

(3) Combustion chambers and heat exchangers;

(4) Fuel oil systems;

(5) Lubricating oil systems;

(6) Details of high temperature characteristics of the materials, including(at the working temperatures) the associated creep rate and rupture strength for the designed service life (where applicable), fatigue strength, corrosion resistance and scaling properties. Particulars of heat treatment, including stress relief;

(7) Calculations of the critical speeds;

(8) Calculations of strength for major components;

(9) Details of the automatic safety devices;

(10) Specifications of gas turbines, including but not limited to the following:

① essential parameters, e.g. mass, time between overhaul, maximum continuous power, maximum air mass flow rate, temperature at main sections, pressure at main sections, revolving speed of gas

generator, revolving speed of power turbine, maximum allowable rate of load increase/reduction and maximum allowable rate of revolving speed increase /reduction;

② Usage limitations, e.g., maximum allowable heel and trim, maximum allowable roll and pitch, maximum allowable axial force of output shaft, maximum allowable shear force and bending moment of output shaft, maximum allowable acceleration load, maximum allowable salt content in inlet air and fuel type, etc.

(11) Other plans and documents as deemed necessary by ISC.

8.1.6.2 The following plans and documents are to be submitted for information:

(1) Principal particulars of gas turbines, characteristics of compressors (including surge margin in various operation conditions), overall performance curves of gas turbines, performance curves indicating power and speed dependency on ambient temperature, gas turbine performance or power loss as a function of operation time, and expected recovery performance after a complete overhaul, etc.;

(2) General section of gas turbines and compressors;

(3) The failure mode and effect analysis (FMEA) of the automatic safety devices;

(4) Operation and maintenance manuals of gas turbines;

(5) Other plans and documents as deemed necessary by ISC.

Section 2 MATERIALS

7.2.1 *General requirements*

7.2.1.1 Materials used for the construction of gas turbine components are to comply with the relevant provisions as specified in ISC Rules for Materials and Welding. Where materials other than those mentioned above are used, relevant documents are to be submitted for approval.

7.2.2 *High temperature properties*

7.2.2.1 Gas turbine components working under high temperature are to have high temperature characteristics consistent with the working temperature (such as creep rate, rupture strength, fatigue strength, corrosion resistance and scaling properties).

7.2.3 *Testing of materials*

7.2.3.1 The following parts of gas turbines are to be in accordance with the relevant requirements for testing of materials in ISC Rules for Materials and Welding:

(1) shafts, turbine and wheel of compressor, guide vanes and blades;

(2) turbine and casing of compressor, combustion chambers and heat exchangers.

For low-power gas turbines, materials of shafts, turbines and wheels of compressors are also to be subject to material tests.

7.2.4 *Non-destructive testing*

7.2.4.1 Non-destructive tests are required for rotating parts (including welded joints),including compressors and turbine rotor shafts, stiff and flexible couplings, bolts for couplings, blades, discs, integral pinions and gears and other dynamically stressed parts. Details including test methods and results are to be assessed in accordance with acceptable recognized standards.

7.2.4.2 Non-destructive tests are required for stationary parts (including castings for casings intended for a temperature exceeding 230℃ and plates for casings intended for a temperature exceeding 370℃ or pressure exceeding 4 MPa). Details including test methods and results are to be assessed in accordance with acceptable recognized standards.

7.2.4.3 Non-destructive tests to piping and associated fittings are to comply with the relevant requirements in Chapter 2 of this PART.

Section 3 DESIGN AND CONSTRUCTION

8.3.1 *General requirements*

8.3.1.1 All parts of gas turbines, compressors, etc., are to have clearances and fits appropriate to and consistent with their respective thermal expansion.

8.3.1.2 Gas turbine bearings are to be so disposed and supported that lubrication cannot be impaired by

hot gas. Effective means are to be provided to prevent leakage oil coming into contact with hot parts.
8.3.1.3 Gas turbines are to be so designed that escape of fragments due to burst of rotors can be avoided as far as practicable.

8.3.2 *Stress analysis*
8.3.2.1 Stress analysis to each rotor including rotor discs, blades and shafts at maximum designed working condition is to be submitted by the manufacturers.

8.3.3 *Vibration*
8.3.3.1 Gas turbine and compressor rotor discs and blades are to be designed and manufactured to be free from undue vibration within the operating speed range. Calculations of the critical speed are to be submitted. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be required.

8.3.4 *Air inlet and exhaust gas systems*
8.3.4.1 The air-inlet system is to be designed to minimize the entrance of harmful foreign matter into the compressors and gas turbines.
8.3.4.2 Appropriate means is to be provided to prevent icing of air inlet pipes.
8.3.4.3 The air-inlet pipelines are to be designed to minimize the risk of loose parts entering the gas turbines due to air flow or corrosion.
8.3.4.4 The air-inlet system is to be provided with appropriate filtering equipment to keep water, particulate matters and corrosive sea salt within the limits specified by gas turbine manufacturers.
8.3.4.5 Where multiple turbines are arranged, each gas turbine is to be provided with separate inlet pipes and exhaust pipes, so that simultaneous operation of turbines is not to harm the operation condition of any turbine and induced circulation through a stopped gas turbine is prevented.
8.3.4.6 Pressure drop of inlet and exhaust systems is not to exceed the range specified by gas turbine manufacturers.
8.3.4.7 The arrangement of the turbine exhaust system is to be such as to prevent exhaust gas being drawn into the compressors.

8.3.5 *Fuel and salt deposits*
8.3.5.1 Where it is intended to burn non-distillate fuels forming harmful deposits, adequate provision is to be made for periodic removal of the deposits.
8.3.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines are to be provided.

8.3.6 *Turning gear*
8.3.6.1 Gas turbines are to be equipped with turning gear. Where gas turbines are provided with remotely controlled starting or automatic starting function, in order to prevent the starting of gas turbines during engagement of turning gear, the turning gear is to be interlocked with starting arrangements. If gas turbines are not provided with remotely controlled starting or automatic starting function, at least safe operation instructions with a warning notice are to be provided, indicating that “Starting of gas turbines during engagement of turning gear is prohibited”.

8.3.7 *Starting system*
8.3.7.1 The starting arrangements and starting air pipe systems are to comply with the relevant provisions as stated in Section 5, Chapter 9 of this PART, where applicable.
8.3.7.2 Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start. Where means are provided for automatic starting, a purging program is to be included in the starting sequence.
8.3.7.3 Starting devices are to be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

8.3.8 *Inspection openings*
8.3.8.1 It is recommended that inspection openings be provided to permit inspection of rotors of the compressors and gas turbines and the inside of the burner with bore scope or other instrument without dismantling the gas turbines.

8.3.9 *Instrumentation*

8.3.9.1 Main propulsion gas turbines are to be provided with monitoring device fitted on the control platforms to display and/or record various principal parameters such as temperature, pressure, speed, etc.

8.3.9.2 Monitoring devices are at least to indicate the following:

(1) air pressure and temperature at compressor inlet;

(2) gas temperature at burner outlet;

(3) lubricating oil pressure and temperature;

(4) rotor speed.

8.3.10 *Installation*

8.3.10.1 Pipes and ducts connected to the turbine casings are to be so designed that no excessive thrust loads or moments are applied to the gas turbines.

8.3.10.2 Platform gratings and fittings in way of the supports are to be so arranged that free expansion of casing can not be restricted.

Section 4 FITTINGS

8.4.1 *Overspeed protection*

8.4.1.1 An overspeed protective device is to be provided near the burners for each shaft of gas turbines to shut off the fuel supply automatically in order to prevent dangerous overspeed.

The overspeed protection values of main gas turbine and auxiliary gas turbine to drive an electric generator are to be 110% and 115% of the rated speed respectively.

8.4.2 *Speed governors*

8.4.2.1 Where a main propulsion gas turbine incorporates a reverse gear, controllable pitch propeller, electric transmission gear or other clutches, a speed governor independent of the overspeed protective device is to be fitted and is to be capable of controlling the speed of the power turbine without bringing the overspeed protective device into action when suddenly unloaded.

8.4.2.2 Where an auxiliary gas turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted and is to comply with the following requirements:

When the maximum step load is added or taken off, instantaneous frequency variation of the power grid is not to exceed ±10% of the rated frequency, and the recovery time for the engine speed (i.e. the time for the speed fluctuation ratio to return to ±1%) is not to exceed 5 s. When the rated load is suddenly taken off, instantaneous speed variation exceeding 10% of the rated speed is allowed provided this does not cause the intervention of the over-speed device as specified in 8.4.1 of this Chapter.

Under various load conditions from no-load to the rated load, variation of speed after being stable is not to exceed ±5% of the rated speed.

The permanent speed variations of A.C. generating sets intended for parallel operations are to be equal as far as possible.

8.4.3 *Low oil pressure protection*

8.4.3.1 Gas turbines are to be provided with low oil pressure protective devices capable of shutting off the fuel supply automatically when lubricating oil pressure is lower than the specified value.

8.4.4 *High gas temperature alarm*

8.4.4.1 Gas turbines are to be provided with high gas temperature alarms to give warning when the gas temperature at burner outlet exceeds the permissible value.

8.4.5 *Flame failure protection*

8.4.5.1 Gas turbines are to be provided with flame failure protective devices capable of shutting off the fuel supply automatically in the event of flame failure in the combustion chambers.

8.4.6 *High temperature alarm for bearings*

8.4.6.1 The bearings of gas turbines are to be provided with high temperature alarms to give warning when the lub oil is going up excessively.

8.4.7 *Hand trip gear*

8.4.7.1 Hand trip gear for shutting of the fuel supply in an emergency is to be provided at the manoeuvring platform of the gas turbines.

8.4.8 *Temperature control*

8.4.8.1 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:
(1) lubricating oil supply;
(2) oil fuel supply (or automatic control of oil fuel viscosity as alternative);
(3) exhaust gas.

8.4.9 *Safety protection*

8.4.9.1 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:
(1) overspeed;
(2) unacceptable lubricating oil pressure drop;
(3) loss of flame during operation;
(4) excessive vibration;
(5) excessive axial displacement of each rotor (except for gas turbines with rolling bearings);
(6) excessive high temperature of exhaust gas;
(7) unacceptable lubricating oil pressure drop of reduction gear;
(8) excessive high vacuum pressure at the compressor inlet.

8.4.10 *Alarming devices*

8.4.10.1 Unless the FMEA required in item 8.1.6.2(3) proves otherwise, main gas turbines are to be provided with alarming and safeguards devices in accordance with the requirements of Table 8.4.10.1, they can be added or omitted, taking into account the result of FMEA specified in item 8.1.6.2(3).
8.4.10.2 Suitable alarms are to be operated by the activation of shutdown devices.

Alarms and Safeguards for Main Gas Turbines *Table 8.4.10.1*

Monitoring parameter	Alarm	Shutdown
Turbine speed	Overspeed	Overspeed
Lubricating oil pressure	Low*	Too low
Lubricating oil pressure of reduction gear	Low*	Too low
Differential pressure across lubricating oil filter	Large	
Lubricating oil temperature	High	
Oil fuel supply pressure	Low	
Oil fuel temperature	High	
Cooling medium temperature	High	
Bearing temperature	High	
Flame and ignition	Failure	Failure
Automatic starting	Failure	
Vibration	Large*	Too large
Axial displacement of rotor	Large	Large
Exhaust gas temperature	High*	Too high
Vacuum pressure at the compressor inlet	High*	Too high
Control system	Loss	

Note: Alarms marked with "*" are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.

Section 5 TESTS AND TRIALS

8.5.1 *General requirements*

8.5.1.1 Turbines covered in 8.1.1.1 of this Chapter are to be subject to following tests and surveys.

8.5.2 *Material test and non-destructive test*

8.5.2.1 All components of turbines are to be subject to material test and non-destructive test according to the relevant requirements of 8.2.3 and 8.2.4 of this Chapter.

8.5.3 *Balance tests*

8.5.3.1 For compressors and gas turbines, all rotors as finished-bladed and complete with half-coupling are to be dynamically balanced.

8.5.4 *Hydraulic tests*

8.5.4.1 All casings (including compressors casings) are to be tested to a hydraulic pressure equal to 1.5 times the maximum working pressure. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

Where hydraulic tests can not be carried out, the manufacturers are to submit for approval, alternative proposals for determining the soundness of the component.

8.5.4.2 Heat exchangers and intercoolers are to be tested to a hydraulic pressure equal to 1.5 times the maximum working pressure on each side.

8.5.5 *Overspeed tests*

8.5.5.1 Before installation, all complete rotors of the gas turbines are at least to be tested at 115% of the rated speed for 5 min.

8.5.6 *Workshop trials*

8.5.6.1 Gas turbines are to be subject to a workshop trial, and the manufacturer's test program is to be submitted to ISC for approval.

8.5.7 *Shipboard trials*

8.5.7.1 After installation on board, each gas turbine, including all starting, control and safety systems, is to be operated to satisfactorily demonstrate its function.

8.5.7.2 Freedom of gas turbine from harmful vibration at speeds within the operating range is to be demonstrated.

8.5.7.3 The reversing characteristics of propulsion turbine plants are to be demonstrated.

8.5.7.4 The function of governor is to be demonstrated.

CHAPTER 9 DIESEL ENGINES

Section 1 GENERAL PROVISIONS

9.1.1 *Application*

9.1.1.1 The design, construction, installation as well as testing and trial of marine diesel engines, including main propulsion diesel engines， diesel engines for driving generators and other diesel engines related to classification, are to comply with the requirements of this Chapter.

9.1.1.2 The certification requirements and product survey of marine diesel engines are to comply with the requirements of Chapter 3, PART ONE of the Rules.

9.1.2 *Definitions*

9.1.2.1 For the purpose of this Chapter:

(1) A type of engine is defined by:

① bore and stroke;

② injection method (direct or indirect);

③ valve and injection operation (by cams or electronically controlled);

④ kind of fuel (liquid, dual-fuel, gaseous);

⑤ working cycle (4-stroke, 2-stroke);

⑥ turbo-charging system (pulsating or constant pressure);

⑦ the charging air cooling system (e.g. with or without intercooler);

⑧ cylinder arrangement (in-line or V)[①];

⑨ cylinder power, speed and cylinder pressures[②];

Notes:

① Requirements for type test of diesel engines with different cylinder arrangement are given in 9.10.2.3.

② Relevant provisions for cylinder power, speed and cylinder pressures are given in 9.10.2.4 and 9.10.2.5.

(2) Low-Speed Engines mean diesel engines having a rated speed of less than 300 rpm.

(3) Medium-Speed Engines mean diesel engines having a rated speed of 300 rpm and above, but less than 1,400 rpm.

(4) High-Speed Engines mean diesel engines having a rated speed of 1,400 rpm and above.

(5) The rated output is defined as the maximum continuous output developed by diesel engines (i.e. the maximum shaft power for which the machinery is to be classed) based on the ambient conditions specified in 1.2.1.3 or 1.2.1.4 of Chapter 1 of this PART. The rated speed is defined as the speed corresponding to the rated output.

9.1.3 *Overload power*

9.1.3.1 Main propulsion diesel engines，diesel engines for driving generators and other diesel engines related to classification are to be capable of running at 110% of the rated output.

9.1.4 *Astern*

9.1.4.1 Main engines are to be reversible except those coupled with variable pitch propellers, reversing gears or electric propulsion generators.

9.1.4.2 Main engines are to have sufficient astern capability to ensure proper control of the ship under normal conditions.

9.1.5 *Minimum steady speed*

9.1.5.1 Main engines are to have good performance at low speeds. In general, the minimum steady speed of diesel engines is to satisfy the following provisions:

(1) for low-speed engines, not more than 30% rated speed;

(2) for medium-speed engines: not more than 40% rated speed;

(3) for high-speed engines: not more than 45% rated speed.

9.1.6 *Manoeuvring*

9.1.6.1 The time required for reversing main engines is not to exceed 15 s. The time for reversal is defined as, when the main engine is running at the minimum steady speed, the time elapsed from the beginning of manoeuvring till starting of running in the opposite direction.

9.1.6.2 An index indicating the "Ahead" and "Astern" directions of the handle or the hand-wheel is to be fitted to the control station. As a common practice, for navigating the ship ahead, the handle is to be pushed forward, or the hand-wheel is to be turned clockwise.
9.1.6.3 An indicator showing the crankshaft rotational direction is to be fitted to the control station, but it may be dispensed with provided the tachometer is of a dual-rotation type.
9.1.6.4 For ships propelled by multiple engines geared on one shaft or more, a centralized control station for main engines is to be installed in the engine room, and is to be provided with interlocking device ensuring the correct operation sequence of main engines, clutches, etc. while manoeuvring. If the centralized control station is installed in the bridge, another control gear is to be provided in the engine room and is to be interlocked with that in the bridge.
9.1.6.5 Devices for quickly cutting off oil fuel supply or other effective arrangements for emergency stopping are to be provided near the main engine control station.

9.1.7 *Interlocking of turning gear*
9.1.7.1 For diesel engine arranged to be remotely controlled or automatically started, a safety interlocking device is to be fitted between the turning gear and the starting arrangement of the main engine in order to prevent the diesel engine being started when the turning gear is under engagement condition.
9.1.7.2 For diesel engine not arranged to be remotely controlled or automatically started, instructions for safety operations or warning notice are at least to be provided in order to prevent the diesel engine being started by mistake when the turning gear is under engagement condition. The warning notice is to specify that diesel engine is not to be started when the turning gear is under engagement condition.

9.1.8 *Vibration and alignment*
9.1.8.1 The vibration and alignment of marine diesel engine shafting are to comply with the relevant requirements as specified in Chapter 12 of this PART.

9.1.9 *Gas fuel engines*
9.1.9.1 In addition to the relevant provisions of this Chapter, gas fuel engines are to comply with the applicable requirements of Appendix 1[①] of this Chapter, ISC Rules for Ships Using Natural Gas Fuels and ISC Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers.

9.1.10 *Electrically controlled diesel engines*
9.1.10.1 Electrically controlled diesel engines are to comply with the relevant requirements of Appendix 2 of this Chapter.

9.1.11 Turbochargers[②]
9.1.11.1 The turbochargers are to be designed to operate under conditions given in 1.2.1, Chapter 1 of this PART. The component lifetime and the alarm level for speed are to be based on 45℃ air inlet temperature.
9.1.11.2 Turbochargers are categorized in three groups depending on served power by cylinder groups (e.g. for a V-engine with one turbocharger for each bank, the size is half of the total engine rated power) with:
(1) Category A: ≤ 1,000 kW;

---

① (1) Appendix 1 applies to gas fuel engines for which the date of an application for type approval certification is dated on or after 1 July 2019.
(2) The "date of application for type approval" is the date of documents accepted by ISC as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.
(3) Engines with an existing type approval on 1 July 2019 are not required to be re-type approved in accordance with the new requirements until the current type approval becomes invalid. For the purpose of certification of these engines, the current type approval and related submitted documentation will be accepted.

② (1) The requirements of 9.1.11, 9.1.12.3, 9.6.2, 9.6.6.2, 9.6.10 and 9.6.11 apply to turbochargers with the date of an application for certification of the new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate on or after 1 January 2023. Turbochargers with an existing type approval on 1 January 2023 are not required to be re-type approved in accordance with the requirement until the current Type Approval reaches its expiry date. The requirements of 9.6.12 apply to turbochargers with the date of application for certification of an individual turbocharger on or after 1 January 2023.
(2) The "date of application for certification" is the date of whatever document ISC requires/accepts as an application or request for certification of a new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

(2) Category B: > 1,000 kW and ≤ 2,500 kW;
(3) Category C: > 2,500 kW.

9.1.11.3 The requirements for turbochargers with regard to design, approval, type testing and certification escalate with the size of the turbochargers. For details, see Section 6 of this Chapter.

9.1.11.4 Turbochargers are to be type approved, either separately or as a part of an engine.

9.1.11.5 The requirements relating to turbochargers in this Chapter are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

9.1.12 *Plans and documents*

9.1.12.1 The following engine plans and documents are to be submitted for approval:

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions[1,2]
2	Thrust bearing bedplate of welded design, with welding details and welding instructions[1]
3	Bedplate/oil sump welding drawings[1]
4	Frame/framebox/gearbox of welded design, with welding details and instructions[1,2]
5	Frame/framebox/gearbox, with welding drawings[1,2]
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to Appendix 3 of this Chapter
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts (see Table 9.2.2.1) with information on non-destructive material tests and pressure tests[3]
12	Schematic layout or other equivalent documents on the engine of starting air system, fuel oil system, lubricating oil system, cooling water system, hydraulic system (including hydraulic system for valve lift), control and safety system
13	Shielding of high pressure fuel pipes, assembly[4]
14	Construction and strength of accumulators (for electronically controlled engine)
15	Arrangement and details of the crankcase explosion relief valve (see 9.7.4)[5]
16	Calculation results for crankcase explosion relief valves (see 9.7.4)
17	Details of the type test program and the type test report[7]
18	High pressure parts for fuel oil injection system[6]
19	Oil mist detection and/or alternative alarm arrangements (see 9.7.6 and 9.7.7)
20	Details of mechanical joints of piping systems (see 2.5.3, Chapter 2 of this PART)
21	Documentation verifying compliance with inclination limits (see 1.2.1, Chapter 1 of this PART)
22	Documents as required in Section 6, Chapter 2, PART SEVEN of the Rules, as applicable

Notes:
1. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
2. For each cylinder for which dimensions and details differ.
3. For comparison with rules requirements for material, NDT and pressure testing as applicable.
4. All engines.
5. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
6. The documentation to contain specifications for pressures, pipe dimensions and materials.
7. The type test program is to be submitted before the type test, and the type test report may be submitted after the conclusion of the type test.

9.1.12.2 The following engine plans and documents are to be submitted for information:

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information (see Annex 3 to Appendix 5 of this Chapter), Project Guide, Marine Installation Manual)
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly[1]
6	Frame/framebox/gearbox of cast design[2]
7	Tie rod

8	Connecting rod
9	Connecting rod, assembly[3]
10	Crosshead, assembly[3]
11	Piston rod, assembly[3]
12	Piston, assembly[3]
13	Cylinder jacket/ block of cast design[2]
14	Cylinder cover, assembly[3]
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly[3]
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
21	For electronically controlled engines, construction and arrangement of control valves, high-pressure pumps and drive for high pressure pumps
22	Operation and service manuals[4]
23	FMEA (for engine control system)[5]
24	Production specifications for castings and welding (sequence)
25	Evidence of quality control system for engine design and in service maintenance
26	Quality requirements for engine production
27	Type approval certification for environmental tests, control components of electrical system[6]
28	Fatigue analysis of high pressure fuel oil piping and hydraulic oil piping (where applicable)
29	Other plans and documents as deemed necessary by ISC

Notes:

1. If integral with engine and not integrated in the bedplate.
2. Only for one cylinder or one cylinder configuration.
3. Including identification (e.g. drawing number) of components.
4. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
5. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.
6. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per ISC Guidelines for Type Approval Test of Electric and Electronic Products.

9.1.12.3 For turbochargers, the following plans and documents are to be submitted for approval:

(1) Category A:

① Containment test report;

② Cross sectional drawing with principal dimensions and names of components;

③ Test program.

(2) Category B and C:

① Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation;

② Documentation of containment in the event of disc fracture (see 9.6.10);

③ Operational data and limitations, including maximum permissible operating speed (rpm), alarm level for overspeed, maximum permissible exhaust gas temperature before turbine, alarm level for exhaust gas temperature before turbine, minimum lubrication oil inlet pressure, lubrication oil inlet pressure low alarm set point, maximum lubrication oil outlet temperature, lubrication oil outlet temperature high alarm set point, maximum permissible vibration levels (i.e. self- and externally generated vibration);

Note: Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%.

④ Arrangement of lubrication system, all variants within a range;

⑤ Type test reports;

⑥ Test program.

(3) In addition to the provisions of (2) above, the following plans and documents for category C turbochargers are to be submitted:

① Drawings of the housing and rotating parts including details of blade fixing;
② Material specifications (chemical composition and mechanical properties) of all parts mentioned above;
③ Welding details and welding procedure of above mentioned parts, if applicable;
④ Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit, see 9.6.6.2;
⑤ Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;
⑥ Operation and maintenance manuals*.

Note: * Applicable to two sizes in a generic range of turbochargers.

Section 2 INSPECTION, TEST AND CERTIFICATION OF DIESEL ENGINE PARTS

9.2.1 *General requirements*

9.2.1.1 The engine manufacturer is to have a quality control system that is suitable for the actual engine types. The quality control system is also to apply to any sub-suppliers. ISC reserves the right to review the system or parts thereof.

9.2.1.2 Materials and components are to be produced in compliance with all the applicable production and quality instructions specified by the engine manufacturer.

9.2.1.3 Certain parts are to be verified and documented by means of ISC Marine Product Certificate (C), Manufacturer's document (W) or Test Report (TR). For the definitions of ISC Marine Product Certificate (C), Manufacturer's document (W) or Test Report (TR), see Chapter 3, PART ONE of the Rules.

9.2.1.4 The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by ISC, the documentation of single tests and inspections may also be arranged by filling in results on a control sheet following the component through the production.

9.2.1.5 The TR and W issued by the manufacturer are to be submitted to ISC for review to ensure compliance with the agreed or approved specifications. ISC Marine Product certificate (C) means that the Surveyor also witnesses the testing, batch or individual, unless Alternative Certification Scheme (ACS) provides other arrangements.

9.2.1.6 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by ISC. The manufacturing works process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

9.2.1.7 The extent of parts to be documented depends on the type of engine, engine size and criticality of the part. Requirements for inspection, test and documentation of diesel engine parts are listed in Table 9.2.2.1.

9.2.1.8 For components and materials not specified in Table 9.2.2.1, consideration will be given by ISC upon full details being submitted and reviewed.

9.2.1.9 Symbols used in Table 9.2.2.1 are listed below.

Symbol	Description
CC	Chemical composition
CH	Crosshead engines
D	Cylinder bore diameter (mm)
M	Mechanical properties
MT	Magnetic particle testing
PT	Dye penetration testing
UT	Ultrasonic testing
VT	Visual examination of accessible surfaces by the Surveyor

9.2.2 *Inspection, test and certification*

9.2.2.1 Diesel engine parts are to be subject to material test, NDT, hydraulic test, dimensional inspection and visual examination as given in Table 9.2.2.1.

9.2.2.2 Turbochargers are to be subject to inspection, test and certification in accordance with the relevant requirements of Section 6 of this Chapter.

9.2.2.3 Crankcase explosion relief valves are to be subject to inspection, test and certification in accordance with the requirements of 9.7.4 of this Chapter.

9.2.2.4 Oil mist detection system is to be subject to inspection, test and certification in accordance with the requirements of 9.7.6 and 9.7.7 of this Chapter.

9.2.2.5 Speed governor and overspeed protection device are to be subject to inspection and test in accordance with the requirements of 9.7.8, 9.7.9 and 9.7.10 of this Chapter.

9.2.2.6 Diesel engine control, alarm and safety protection system (including computer system) are to be subject to inspection and test in accordance with the relevant requirements of PART SEVEN of the Rules.

9.2.2.7 Material test and non-destructive testing are to be carried out in accordance with the relevant requirements of ISC Rules for Materials and Welding.

9.2.2.8 Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, relevant documents are to be submitted for confirmation.

Summary of inspection, test and certification of diesel engine parts *Table 9.2.2.1*

Item	Parts [5]	Material properties [1]	Non-destructive examination [2]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
1	Welded bedplate	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
2	Bearing transverse girders (cast steel)	CC+M	UT+MT/PT			VT	All
3	Welded frame box	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
4	Cylinder block (cast iron)			X[4]			>400 kW/cyl
5	Welded cylinder frames	CC+M	UT+MT/PT			VT(fit-up and post-welding)	CH
6	Engine block (grey cast iron)			X[4]			>400 kW/cyl
7	Engine block (nodular graphite cast iron)	M		X[4]			>400 kW/cyl
8	Cylinder liner	CC+M		X[4]			D>300mm
9	Cylinder head (cast iron)			X			D>300mm
10	Cylinder head (cast steel)	CC+M	UT+MT/PT	X		VT	D>300mm
11	Forged cylinder head	CC+M	UT+MT/PT	X		VT	D>300mm
12	Piston crown (cast steel)	CC+M	UT+MT/PT			VT	D>400mm
13	Forged piston crown	CC+M	UT+MT/PT			VT	D>400mm
14	Crankshaft: made in one piece	CC+M	UT+MT/PT		X	VT (random, of fillets and oil bores)	All
15	Semi-built crankshaft (Crank throw, forged main journal and journals with flange)	CC+M	UT+MT/PT		X	VT (random, of fillets and shrink fittings)	All
16	Exhaust gas valve cage			X			CH
17	Piston rod	CC+M	UT+MT/PT			VT (random)	D>400mm CH
18	Cross head	CC+M	UT+MT/PT			VT (random)	CH
19	Connecting rod with cap	CC+M	UT+MT/PT		X	VT (random, of all surfaces, in particular those shot peened)	All
20	Coupling bolts for crankshaft	CC+M	UT+MT/PT		X	VT (random, of interference fit)	All

Item	Parts [5)]	Material properties [1)]	Non-destructive examination [2)]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
21	Bolts and studs for main bearings and cylinder heads	CC+M	UT+MT/PT				D>300mm
22	Bolts and studs for connecting rods	CC+M	UT+MT/PT		X (thread making)		D>300mm
23	Tie rod	CC+M	UT+MT/PT		X (thread making)	VT (random)	CH
24	High pressure fuel injection pump body	CC+M		X			All
25	High pressure fuel injection valves (only for not autofretted)			X			All
26	High pressure fuel injection pipes including common fuel rail	CC+M		X for those that are not autofretted			All
27	High pressure common servo oil system	CC+M		X			All
28	Cooler, both sides [3)]	CC+M		X			D>300mm
29	Accumulator	CC+M		X			All engines with accumulators with a capacity of >0.5 l
30	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	CC+M		X			>800 kW/cyl
31	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 24 and 30			X			>800 kW/cyl
32	Bearings for main, crosshead, and crankpin	CC	UT (full contact between basic material and bearing metal)		X		>800 kW/cyl

Notes:

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MT or PT. When certain NDE method on the finished component is impractical (for example UT for items 10/11), the NDE method can be performed at earlier appropriate stages in the production of the component, see 3.1.5.2, PART ONE of the Rules.

(3) Charge air coolers need only be tested on the water side.

(4) Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

(5) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. The certification requirements for relevant components are to comply with the requirements of Chapter 3, PART ONE of the Rules.

Section 3 DESIGN AND CONSTRUCTION

9.3.1 *Design*

9.3.1.1 Design and construction of diesel engines are to comply with relevant requirements relating to ambient condition, properties and availability specified in Section 2, Chapter 1 of this PART.

9.3.1.2 Fatigue strength calibration or diameter calibration may be adopted in calculating crankshafts of

diesel engines. For details, see Appendix 3 of this Chapter.

9.3.2 *Materials*

9.3.2.1 The specified tensile strength of forgings and castings for crankshafts is in general to be selected within the following limits, and the materials used are to comply with the relevant requirements contained in ISC Rules for Materials and Welding:

(1) carbon and carbon-manganese steel 400 to 600 N/mm^2;

(2) alloy steel 600 to 1,000 N/mm^2;

(3) nodular graphite cast iron 490 to 780 N/mm^2.

9.3.2.2 Where it is proposed to use alloy steel forgings for crankshafts, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

9.3.3 *Structure*

9.3.3.1 Frames and bedplates of diesel engines are to be stress-relieved. Where valid documentation and evidence are provided by the manufacturer or the designer, the stress-relieved treatment is unnecessary. In the case of welded structure, they are to meet, furthermore, the relevant requirements in ISC Rules for Materials and Welding.

Section 4 PIPING SYSTEMS

9.4.1 *Lubricating oil systems*

9.4.1.1 The lubricating oil systems of diesel engines are to be so designed and installed as to maintain operation when the ship is under a list or trim up to that as given in 1.2.1.1 of Chapter 1 of this PART.

9.4.1.2 Diesel engines greater than 37 kW are to be provided with an audible and visible alarm device giving an indication of failure of lubricating oil systems.

9.4.1.3 Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged at their outlet ends.

9.4.1.4 In addition, the lubricating oil systems are to comply with the relevant requirements of Section 6, Chapter 4 of this PART.

9.4.2 *Cooling water systems*

9.4.2.1 For large low-speed diesel engine having oil-cooled or water-cooled pistons, a thermometer and a device for observing the circulation of cooling oil or cooling water are to be fitted to each outlet pipe led from the inside of the piston. If there is no outlet pipe led from the inside of the piston, other means of arrangement may be adopted.

9.4.2.2 Cooling water systems of diesel engines are to be provided with alarm devices for indicating the excess temperature.

9.4.2.3 In addition, the cooling water systems are to comply with the relevant requirements of Section 5, Chapter 4 of this PART.

9.4.3 *Oil fuel systems*

9.4.3.1 For cargo ships of 500 gross tonnage and over and all passenger ships, high-pressure fuel delivery lines are to meet the relevant requirements of PART SIX of the Rules.

For cargo ships of less than 500 gross tonnage, where the cylinder bore of main and auxiliary diesel engines is 250 mm and above, the fuel injection piping is to be effectively secured and shielded so as to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage.

9.4.3.2 Where, on V-type engines, the fuel system is located between the rows of cylinders, suitable shielding and drainage ducts for leaking fuel are to be provided.

9.4.3.3 Leaking fuel is to be safely drained away at zero excess pressure. Care is to be taken to ensure that leaking fuel cannot become mixed with the engine lubricating oil.

9.4.3.4 Where the engine is installed on elastic mountings, the approved flexible joints are to be fitted in way of connection between the diesel engine and fuel oil supply pipes. The flexible joints are to comply with relevant requirements of Section 5, Chapter 2 of this PART.

9.4.3.5 In addition, the oil fuel systems are to comply with the relevant requirements of Section 2, Chapter 4 of this PART.

9.4.4 *Exhaust systems*

9.4.4.1 An instrument for measuring the exhaust gas temperature is to be fitted to each cylinder of diesel engines with cylinder bore 200 mm and over.

9.4.4.2 The exhaust pipes of diesel engines are to be provided with effective silencers or other equivalent silencing measures.

9.4.4.3 Each diesel engine is to have a separate exhaust pipe to prevent the backflow of the exhausts. Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.

9.4.4.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the diesel engine.

9.4.4.5 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

9.4.4.6 In addition, the exhaust systems are to comply with the relevant requirements of Section 10, Chapter 4 of this PART.

9.4.5 *Starting air systems*

9.4.5.1 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

9.4.5.2 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system.

9.4.5.3 The starting air piping system is to be protected against the effects of explosions due to the improper function of the starting valve by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

9.4.5.4 In diesel engines having cylinders exceeding 230 mm, bursting discs or flame arresters or other equivalent means are to be fitted in the starting air systems, such devices are to be fitted at the starting valves on each cylinder for direct reversing engines and at the supply inlet to the starting air manifold for non-reversing engines.

Section 5 STARTING ARRANGEMENTS

9.5.1 *Mechanical starting arrangements*

9.5.1.1 The arrangement for air starting is to be such that the necessary air for the first charge can be produced on board without external aid.

9.5.1.2 Where the main engine is arranged for starting by compressed air, two or more air compressors are to be fitted. At least one of the compressors is to be driven independent of the main propulsion unit and is to have the capacity not less than 50% of the total required.

The total capacity of air compressors is to be sufficient to supply within one hour the quantity of air needed to satisfy 9.5.1.6 by charging the receivers from atmospheric pressure. The capacity is to be approximately equally divided between the number of compressors fitted, excluding an emergency compressor which may be installed to satisfy the requirements of 9.5.1.1.

9.5.1.3 Pressure gauges and safety valves are to be fitted to air compressors. The safety valves are to be set at a pressure not more than 1.1 times the working pressure. Casings of the cooling water space of compressed air coolers are to be provided with relief valves or bursting discs.

9.5.1.4 Relief valves are to be fitted to the crankcase of air compressors when the crankcase has a volume exceeding 0.6 m^3.

9.5.1.5 The design and construction of air receivers are to comply with the relevant requirements contained in Section 4 and Appendix 4, Chapter 6 of this PART.

9.5.1.6 Where the main engines are arranged for starting by compressed air, at least two starting air receivers of about equal capacity are to be fitted, which can be used independently. The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque. When other consumers such as auxiliary engines starting systems, control systems, whistle, etc., are to be connected to starting air receivers, their air consumption is also to be taken into account. Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced to 3 times, the total number of starts is not to be less than 12 times, but

unnecessarily exceed 18 times.
9.5.1.7 The air receivers are to be so fitted with drain arrangement as to permit effective drainage when the ship is under normal inclination conditions.

9.5.2 *Electric starting installations*

9.5.2.1 Where the main engine is arranged for electric starting, two separate batteries are to be fitted. The arrangement is to be such that the batteries cannot be connected in parallel. Each battery is to be capable of starting the main engine when in cold and ready to start conditions. The combined capacity of the batteries is to be sufficient without recharging to provide within 30 min the number of starts of main engines as required in 9.5.1.6 of this Section in case of air starting.
9.5.2.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or may be supplied by separate circuits from the main engine batteries when such are provided. In the case of a single auxiliary engine only one battery may be required. The capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.
9.5.2.3 The starting batteries are to be used for starting and the engines own monitoring purposes only. Provisions are to be made to maintain continuously the stored energy at all times.

9.5.3 *Starting arrangements for emergency generating sets*

9.5.3.1 The prime mover of emergency generating sets is to be capable of being started in cold condition at a temperature of 0℃. If this is impracticable, or if lower temperatures are likely to be encountered, an accessory heating arrangement may be fitted so as to ensure low-temperature starting of the emergency generating sets.
9.5.3.2 Each emergency generating set arranged to be automatically started is to be equipped with starting devices with a stored energy capability of at least three consecutive starts. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy is to be provided for an additional three starts within 30 min unless manual starting can be demonstrated to be effective.
9.5.3.3 The stored energy is to be maintained at all times as follows:
(1) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.
(2) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if, electrically driven, is supplied from the emergency switchboard.
(3) All of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.
9.5.3.4 Where automatic starting is not required, manual starting is permissible, such as manual cranking, inertia starts, manually charged hydraulic accumulators, or powder charge cartridges, where they can be demonstrated as being effective.
When manual starting is not practicable, the requirements of 9.5.3.2 and 9.5.3.3 are to be complied with except that starting may be manually initiated.
9.5.3.5 Where the emergency generating sets are provided with electronic speed governors (or other auxiliary facilities which are only able to start after being supplied with electric power), two sets of power supply which are independent from each other are to be provided.
9.5.3.6 The emergency generator used to restore operation from the dead ship condition is to comply with the provisions of 1.2.6, Chapter 1 of this PART.

Section 6 SCAVENGING AND SUPERCHARGING ARRANGEMENTS

9.6.1 *Lubricating oil systems*

9.6.1.1 The lubricating oil system of exhaust gas turbochargers may be separate from, or in common with, that of the main engine. If lubricating oil pumps are not directly driven by turbochargers, an independent standby lubricating oil pump is to be provided. And in addition, large low-speed diesel engines are to be provided with lubricating oil gravity tanks for emergency. Lubricating oil systems are to be arranged according to the requirements of 1.2.1.1 of this PART.

9.6.2 *Alarm and monitoring*

9.6.2.1 For all turbochargers of Categories B and C, indications and alarms as listed in Table 9.6.2.1 are required.
9.6.2.2 Indications may be provided at either local or remote locations.

Requirements for alarm and indication of turbochargers of categories B and C

Table 9.6.2.1

Pos.	Monitored Parameters	Category of Turbochargers				Remark
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High (4)	X (4)	High (4)	X (4)	
2	Exhaust gas at each turbocharger inlet, temperature	high (1)	X (1)	high	X	High temp. alarms for each cylinder at engine is acceptable (2)
3	Lub. oil at turbocharger outlet, temperature			high	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	low	X	low	X	Only for forced lubrication systems (3)

Notes:
(1) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.
(2) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.
(3) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.
(4) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

9.6.3 *Air filters and silencers*
9.6.3.1 Turbochargers are to be fitted with inlet air filters and silencers.

9.6.4 *Rotor shaft locking devices*
9.6.4.1 Turbocharger rotor shafts are to be provided with locking devices. If not, by-pass connections or other suitable devices are to be fitted to the pipes before and after the turbines to ensure the normal operation of main engines in case of turbocharger breakdown.

9.6.5 *Critical speeds*
9.6.5.1 Critical speeds of the turbocharger rotor are to be determined by calculation. In the case of rigid rotor shafts, critical speeds are not to be less than 1.3 times the rated speed.

9.6.6 *Rotors and rotor shafts*
9.6.6.1 Where rotor shafts are of welded construction, they are to meet the relevant requirements in ISC Rules for Materials and Welding.
9.6.6.2 For turbochargers of category C, in cases where the disc is connected to the shaft with interference fit, calculations is to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.
9.6.6.3 After assembly, rotors are to be dynamically balanced.

9.6.7 *Protection*
9.6.7.1 For two-stroke loop-scavenged and cross-scavenged diesel engines, grids or other suitable devices are to be fitted before turbine nozzles to prevent broken piston rings from entering into the turbine casings.
9.6.7.2 It is undesirable to connect vent pipes of crankcase with turbocharger inlets. Otherwise, effective oil vapor separating devices are to be fitted before the turbocharger inlets.

9.6.8 *Emergency blowers*
9.6.8.1 Two-stroke turbocharged diesel engines not equipped with scavenge pumps are to be provided with independent emergency blowers, except that the scavenging air systems arranged in series are available.

9.6.9 *Relief valves of scavenging air receivers and fire extinguishing devices*

9.6.9.1 Scavenging air receivers of two-stroke diesel engines are to be fitted with relief valves as well as devices for removing dirty oil and condensate. Relief valves are to be set generally at a pressure not more than 1.1 times the maximum scavenging air pressure.

9.6.9.2 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with independent fire extinguishing arrangements which are to be independent of the fire extinguishing system of the engine room.

9.6.10 *Containment*

9.6.10.1 Turbochargers are to fulfil containment in the event of a rotor burst. This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it is to be assumed that the discs disintegrate in the worst possible way.

9.6.10.2 For category B and C, containment is to be documented by testing. Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

9.6.10.3 The minimum test speeds, relative to the maximum permissible operating speed, are:

— for the compressor: 120%;

— for the turbine: 140% or the natural burst speed, whichever is lower.

9.6.10.4 Containment tests are to be performed at a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

9.6.10.5 Manufacturers are to determine whether cases more critical than those defined in 9.6.10.3 and 9.6.10.4 exist with respect to containment safety. Where such a case is identified, evidence of containment safety is also to be provided for that case.

9.6.10.6 A numerical analysis simulation such as Finite Element Method (FEM) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:

(1) the numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests;

(2) the corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test;

(3) material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated;

(4) the design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.

Note: A generic range means a series of turbocharger which are of the same design, but scaled to each other.

9.6.10.7 In cases where a totally new design is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

Note: Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.

(1) Maximum permissible exhaust gas temperature;
(2) Number of bearings;
(3) Number of turbine blades;
(4) Number of turbine wheels and/or compressor wheels;
(5) Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation);
(6) Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type).

9.6.11 *Type testing*

9.6.11.1 Type testing is applicable to categories B and C. The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

9.6.11.2 Turbochargers for the low, medium, and high-speed engines are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see Appendix 4 of this Chapter.
9.6.11.3 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.
9.6.11.4 The rotor vibration characteristics are to be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.
9.6.11.5 The type test is to be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger is to be opened for examination, with focus on possible rubbing and the bearing conditions.
9.6.11.6 The extent of the surveyor's presence during the various parts of the type tests is left to the discretion of each Society.

9.6.12 *Certification*
9.6.12.1 The manufacturer is to adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.
9.6.12.2 For category C, this is to be verified by means of periodic product audits of Alternative Certification Scheme (ACS, see Section 10, Chapter 3, PART ONE of the Rules).
9.6.12.3 These audits are to focus on:
(1) chemical composition of material for the rotating parts;
(2) mechanical properties of the material of a representative specimen for the rotating parts and the casing;
(3) UT and crack detection of rotating parts, or other non-destructive testing as applicable;
(4) dimensional inspection of rotating parts;
(5) rotor balancing;
(6) hydraulic testing of cooling spaces to 0.4MPa or 1.5 times the maximum working pressure, whichever is higher;
(7) overspeed test of all compressor wheels for a duration of 3 min at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45 ℃ inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.
9.6.12.4 The certification requirements for turbochargers are to be in compliance with Chapter 3, PART ONE of the Rules.
9.6.12.5 The requirements of 9.6.12.1 to 9.6.12.4 also apply to replacement of rotating parts and casing.
9.6.12.6 Alternatively to the above periodic product audits, individual certification of a turbocharger and its parts may be made. However, such individual certification of category C turbocharger and its parts are to be based on test requirements specified in 9.6.12.3.

Section 7 FITTINGS

9.7.1 *Indicator valves*
9.7.1.1 An indicator valve is to be fitted to each cylinder cover of diesel engines having cylinder bore over 200 mm.

9.7.2 *Cylinder Safety valves*
9.7.2.1 A safety valve or equivalent means to prevent overpressure in the cylinders is to be fitted to each cylinder cover of diesel engines having cylinder bore over 230 mm. The safety valve is to be set at a pressure not more than 1.40 times the maximum combustion pressure and is to be so arranged that personal injury will not be caused by the outburst gas. For auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

9.7.3 *Crankcases*
9.7.3.1 Crankcases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.
9.7.3.2 The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

9.7.4 *Crankcase relief valves*

9.7.4.1 In engines having cylinders not less than 200 mm bore or having a crankcase gross volume not less than 0.6 m^3, relief valves are to be installed according to the requirements of 9.7.4.2 to 9.7.4.6 of this Section.
9.7.4.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least one relief valve is to be fitted near respectively each end of crankcase and an additional relief valve is to be fitted near the middle of the engine, where crank throws exceed eight.
9.7.4.3 In engine having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. Relief valves are to be arranged from each end, where the cranks are of odd number.
9.7.4.4 In engines having cylinders exceeding 300 mm bore at least one relief valve is to be fitted in way of each main crank throw.
9.7.4.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0.6 m^3.
9.7.4.6 The structural design of crankcase relief valves are to satisfy following requirements:
(1) The combined free area of the crankcase relief valves fitted on an engine is not to be less than 115 cm^2 per m^3 of the volume of the crankcase. The free area of each relief valve is not to be less than 45 cm^2.
(2) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter.
(3) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.
(4) Crankcase explosion relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0.02 MPa.
(5) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.
(6) Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valves.
(7) Crankcase explosion relief valves are to be provided with a copy of manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:
① description of valve with details of function and design limits;
② copy of type test certification;
③ installation instructions;
④ maintenance in service instructions to include testing and renewal of any sealing arrangements;
⑤ actions required after a crankcase explosion.
(8) A copy of the installation and maintenance manual required by 9.7.4.6(7) of this Section is to be provided on board ship.
(9) Valves are to be provided with suitable markings that include the following information:
① name and address of manufacturer;
② designation and size;
③ month/Year of manufacture;
④ approved installation orientation.
(10) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine in accordance with Appendix 7 of this Chapter.

9.7.5 *Vent pipes*
9.7.5.1 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, are in principle not permitted except for gas fuel engines where crankcase ventilation is to be provided in accordance with the applicable requirements of Appendix 1 of this Chapter, ISC Rules for Ships Using Natural Gas Fuels and ISC Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers. Vent pipes, where provided, are to be as small as practicable to minimise the inrush of external air after a crankcase explosion.
9.7.5.2 In order to avoid the interconnection between crankcases and the possible spread of fire following an explosion, interconnection of ventilating pipes of two or more engines is not permitted nor that of oil drain pipes of crankcase.
9.7.5.3 If provision is made for the extraction of gases from within the crankcase, e.g. for smoke detection purpose, the vacuum within the crankcase is not to exceed 25 mm of water column.

9.7.6 Alarms①

9.7.6.1 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required for alarm and slowdown purposes for low speed diesel engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

9.7.6.2 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required for alarm and automatic shutoff purposes for medium and high speed diesel engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

9.7.6.3 Oil mist detection arrangements are to be of a type approved by classification societies and tested in accordance with Appendix 8 of this Chapter and comply with the requirements of 9.7.7 of this Section. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by classification societies for such purposes.

9.7.7 *Crankcase oil mist detection/monitoring system*

9.7.7.1 Crankcase oil mist detectors are to comply with the relevant requirements of PART SEVEN of the Rules in addition to 9.7.7.2 to 9.7.7.13 of this Section.

9.7.7.2 The oil mist detection/monitoring system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

(1) Schematic layout of engine oil mist detection/monitoring and alarm system showing location of engine crankcase sample points and piping or electrical cable arrangements together with pipe dimensions to detector/monitor.

(2) Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.

(3) The manufacturer's maintenance and test manual.

(4) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist monitoring equipment.

9.7.7.3 A copy of the oil mist detection/monitoring equipment maintenance and test manual required by 9.7.7.2 is to be provided on board ship.

9.7.7.4 Oil mist monitoring and alarm information is to be capable of being read from a safe location away from the engine.

9.7.7.5 Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.

9.7.7.6 Oil mist detection/monitoring and alarm systems are to be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions in accordance with accepted test procedures.

9.7.7.7 The oil mist detection/monitoring arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

9.7.7.8 The oil mist detection/monitoring system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

9.7.7.9 Where oil mist detection/monitoring equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with relevant requirements of PART SEVEN of the Rules.

9.7.7.10 The equipment together with detectors/monitors is to be tested when installed on the test bed and on board ship to demonstrate that the detection/monitoring and alarm system functionally operates. The testing arrangements are to be submitted to ISC for approval.

9.7.7.11 Where sequential oil mist detection arrangements are provided for each crankcase, the sampling frequency and time is to be as short as reasonably practicable.

9.7.7.12 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, the following information is to be included in the details to be submitted for approval:

(1) Engine particulars – type, power, speed, stroke, bore and crankcase volume;

(2) Details of arrangements prevent the build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements;

(3) Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience;

---

① For equivalent devices for high speed engines, refer to UI SC133.

(4) Operating instructions and the maintenance and test instructions.

9.7.7.13 Where it is proposed to use the introduction of inert gas into the crankcase to minimize a potential crankcase explosion, details of the arrangements are to be submitted for approval.

9.7.8 *Governors*

9.7.8.1 Main engines are to be provided with efficient governors to ensure that the speed of main engines does not exceed 115% of the rated speed.

9.7.8.2 When electronic speed governors of main engines form part of a remote control system, they are to comply with the following conditions:

(1) If lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, back-up power supply is to be provided.

(2) Local control of the engines is always to be possible even in the case of failure in any part of the automatic or remote control systems, and to this purpose, from the local control position it is to be possible to disconnect the remote signal. A separate governor may be additionally fitted to satisfy the requirements for speed control specified in 9.7.8.1.

(3) Electronic speed governors and their actuators are to be type tested in accordance with ISC Guidelines for Type Approval Test of Electric and Electronic Products.

9.7.9 *Overspeed protective devices*

9.7.9.1 For each main engine developing 220 kW and above which drives a controllable pitch propeller or which can be declutched from the transmission shafting, an overspeed protective device is to be provided in addition to the governor prescribed in 9.7.8.1, so as to prevent the speed of main engines exceeding 120% of the rated speed. Equivalent arrangements may also be accepted subject to special consideration. Overspeed protective devices (including the driving mechanism) are to be independent of governors required by 9.7.8.1.

9.7.10 *Governors for generating sets*

9.7.10.1 Diesel engines intended for driving electric generators are to be provided with governors, which are to meet the following requirements:

They will prevent transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 s, when the maximum electrical step load is switched on or off. When the rated load is suddenly taken off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 9.7.10.3.

In various load conditions between no load and rated load, the permanent speed variation is not to exceed ±5% of the rated speed.

The selected prime mover is to satisfy the load demand within the ship's mains. Two step application of electrical load is to be achieved with the following method:

When 50% of the rated load is suddenly applied from no-load condition to the prime mover, followed by the remaining 50% load after an interval sufficient to restore the speed to steady state, the momentary variation in speed is not to exceed 10% of the rated speed, the recovery time for the engine speed (i.e. the time for speed fluctuation ratio to return to ±1%) is not to exceed 5 s.

Note: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

For a prime mover for which only more than 2 load steps can be achieved, such load steps may be permitted provided that the use of such prime movers is permitted by the condition of ship's electrical network and such prime mover has been considered and approved for use at the design stage. Verification is to be carried out at ship's trials. When a four-stroke diesel engine with high supercharge is used as the prime mover for driving generator, application of electrical load in more than 2 load steps can be permitted in its governing characteristics tests (see Figure 9.7.10.1). Thus, the power necessary electrical installations being automatically switched on after block-out and the sequence in which it is connected are to be sufficiently considered in designing the load of ship's electric power station. This also applies analogously for generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off.

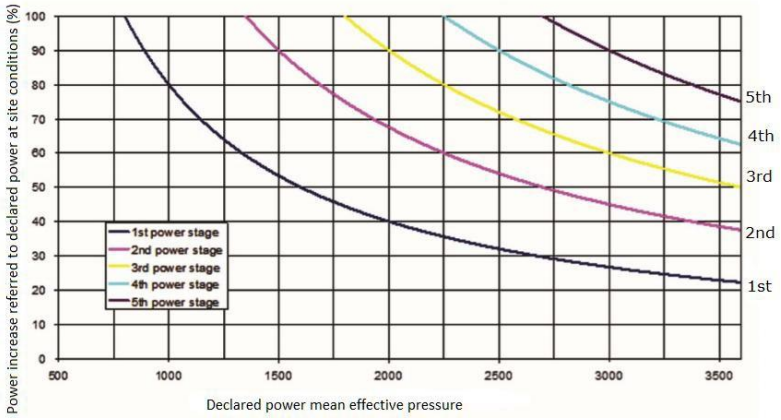


Figure 9.7.10.1①

9.7.10.2 Emergency generator sets must satisfy the governor conditions as per 9.7.10.1 even when their total consumer load is applied suddenly or in steps, subject to:
(1) the total load is supplied within 45 seconds since power failure on the main switchboard;
(2) the maximum step load is declared and demonstrated;
(3) the power distribution system is designed such that the declared maximum step loading is not exceeded;
(4) the compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials.
9.7.10.3 For diesel engines driving electric generators and having a rated power of 220 kW and above, separate overspeed protective devices are to be provided in addition to the governors prescribed in 9.7.10.1, so as to prevent the speed of diesel engines exceeding 115% of the rated speed.
9.7.10.4 The construction and performance of governors for diesel engines intended for driving electric generators are to be in accordance with the relevant provisions specified in Chapter 3, PART FOUR of the Rules. If the generating sets are arranged to operate in parallel, their permanent speed variations are to be the same as far as possible.

9.7.11 *Instrumentation*

9.7.11.1 Tachometers and other necessary measuring instruments are to be fitted to diesel engines. Restricted speed ranges are to be marked red on tachometers.

9.7.12 *Warning notice*

9.7.12.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

Section 8 INSTALLATION

9.8.1 *Bedplates*

9.8.1.1 Bedplates of main engines are to be reasonably rigid, and are to be securely fixed to the engine seatings of reasonable rigidity by means of holding-down bolts, or bolts and chocks, or bolts and thrust sleeves.
When holding-down bolts only are used, the number of fitting bolts is in general not to be less than 15% of the total number.
9.8.1.2 For installation of main engines, consideration is to be given to the effects of the engines on

① (1) The newly revised figure of multiple load steps of four-stroke diesel engines applies to speed governors for which an application for certification is dated on or after 1 January 2020 or which are installed in new ships contracted for construction on or after 1 January 2020.
(2) The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and shipbuilder
(3) The "date of application for certification" is the date of whatever document ISC requires/accepts as an application or request for certification of a speed governor.

crankshaft deflection in cold or hot condition. The crankshaft deflection of an installed engine is to be in accordance with the manufacturer's requirements for installation.

Section 9 ALARMS AND SAFEGUARDS FOR EMERGENCY DIESEL ENGINES

9.9.1 *General requirements*

9.9.1.1 Emergency diesel engines mainly include:
(1) a diesel engine generator used as the emergency source of electrical power;
(2) a diesel engine used to power the emergency fire pump;
(3) a diesel engine generator used as the independent source of power required for steering gear;
(4) other diesel engines used in an emergency.
9.9.1.2 This Section applies to diesel engines, which use distillate marine fuels covered by ISO 8217:2017, required to be immediately available in an emergency and capable of being controlled remotely or automatically operated.

9.9.2 *Alarms and safeguards*

9.9.2.1 The safety and alarm systems are to be designed to "fail safe" and satisfy the requirements of 2.1.3, PART SEVEN of the Rules.
9.9.2.2 Regardless of the engine output, shutdowns other than the overspeed shutdown specified in Table 9.9.2.5 are to be automatically overridden when the engine is in automatic or remote control mode during navigation.
9.9.2.3 The alarm system is to function in accordance with the relevant requirements of PART SEVEN of the Rules, with additional requirements that grouped alarms are to be arranged in the bridge.
9.9.2.4 In additional to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.
9.9.2.5 Emergency diesel engines are to be fitted with alarms and safeguards in accordance with the requirements of Table 9.9.2.5. Local indications of at least those parameters listed in Table 9.9.2.5 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

Alarms and Safeguards for Emergency Diesel Engines *Table 9.9.2.5*

Parameter	Alarm activation	Shutdown with alarm
Lubricating oil pressure	Low	
Lubricating oil temperature①	High	
Temperature of cooling water or cooling air	High	
Pressure or flow of cooling water①	Low	
Overspeed activated①	Overspeed	Shutdown
Fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	Oil leakage	
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing)②	High	

Note: ① for engines having a power of or more than 220 kW.
② only for engines having a power of not less than 2,250 kW or a cylinder bore of more than 300 mm.

Section 10 SURVEY AND CERTIFICATION

9.10.1 **Approval and certification of diesel engines①**

① (1) The new requirements of type approval and type testing (including Appendix 4 and Appendix 5 of this Chapter) apply to engines for which the date of an application for type approval certification is dated on or after 1 July 2016.
(2) The "date of application for type approval" is the date of documents accepted by ISC as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the

9.10.1.1 The type approval of diesel engines consists of drawing and specification approval, conformity of production, approval of type testing program, type testing of engines, review of the obtained type testing results, evaluation of the manufacturing arrangements and issue of a type approval certificate.
9.10.1.2 For each type of engine that is required to be approved, a Type Approval Certificate is to be obtained by the engine designer, and the maximum period of validity of a Type Approval Certificate is for 5 years. The process details for obtaining a Type Approval Certificate are given in Appendix 5 of this Chapter.
9.10.1.3 Each diesel engine intended for installation onboard a ship classed with ISC is to have a ISC marine product certificate. The certification process details for obtaining the engine certificate are in Appendix 5 "Approval and Certification of Diesel Engines" of this Chapter.

9.10.2 Type testing①

9.10.2.1 Type testing is required for every new engine type intended for installation onboard ships subject to classification in accordance with the requirements of Appendix 4 of this Chapter.
9.10.2.2 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to ISC.
9.10.2.3 One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to ISC' discretion, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.
Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.
9.10.2.4 The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR). Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design appraisal is obtained ①②) may be permitted without a new type test if the increase from the type tested engine is within:
(1) 5% of the maximum combustion pressure, or
(2) 5% of the mean effective pressure, or
(3) 5% of the rpm.
Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:
(1) 10% of the maximum combustion pressure; or
(2) 10% of the mean effective pressure, or
(3) 10% of the rpm.

Notes:
①Where those engine data increase from the approved engine type, the crankshaft strength is to be reappraised, and the modified calculations and documents are to be submitted for approval.
② In this Chapter, design appraisal means evaluation of all drawings, information and calculations related to the design. See Glossary in Annex 1 of Appendix 5 of this Chapter.

9.10.2.5 If an engine has been subject to design appraisal, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report at:
(1) test at over speed (only if nominal speed has increased);
(2) rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, 2 measurements with one running hour in between;
(3) maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., 0.5 h;
(4) 100% power at maximum permissible speed corresponding to load point 2, 0.5 h.
9.10.2.6 An integration test demonstrating that the response of the complete mechanical, hydraulic and

---

one previously type approved, or for renewal of an expired type approval certificate.
(3) Engines with an existing type approval on 1 July 2016 are not required to be re-type approved in accordance with the new requirements until the current type approval becomes invalid. The certification of such engines may be carried out in accordance with the current type approval and related submitted documentation.

electronic system is as predicted maybe carried out for acceptance of sub-systems (Turbo Charger, Engine Control System, Dual Fuel, Exhaust Gas treatment, etc.) separately approved. The scope of these tests is to be proposed by the designer/licensor taking into account of impact on engine.

9.10.3 *Works acceptance test and shipboard trials*

9.10.3.1 Factory acceptance test and shipboard trials of diesel engines are to be carried out in accordance with Appendix 6 of this Chapter.

9.10.3.2 The scope of test loads for various engine applications given in Appendix 6 may be expanded depending on the engine application, service experience, or other relevant reasons.

9.10.3.3 Alternatives to the detailed tests may be agreed between the manufacturer and ISC when the overall scope of tests is found to be equivalent to the provisions of Appendix 6.

Appendix 1 SAFETY OF LOW PRESSURE GAS FUEL ENGINES

1 *General Requirements*

1.1 Application and scope

1.1.1 This Appendix applies to trunk piston low pressure gas fuel engines supplied with natural gas as fuel. This Appendix only specifies relevant requirements for the use of gas fuel, and in addition, gas fuel engines are to comply with relevant provisions of this Chapter.

1.1.2 This Appendix is only supplementary to the rules. Gas fuel engines intended for gas carriers are to comply with relevant provisions of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Gas fuel engines intended for ships other than gas carriers are to comply with relevant provisions of ISC Rules for Ships Using Natural Gas Fuels.

1.1.3 Specific requirements of ISC Rules for Ships Using Natural Gas Fuels as referenced in this Appendix are to be applied to gas fuel engines installed on any ship, regardless of type, size and trading area, as long as ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk is not referenced or explicitly specified otherwise.

1.1.4 Gas fuel engines can be either dual fuel engines or gas fuel only engines. Gas fuel can be introduced as follows:

(1) into the air inlet manifold, scavenge space, or cylinder air inlet channel port; or

(2) mixed with air before the turbo-charger ("pre-mixed engines").

The gas / air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

1.1.5 This Appendix covers the following applications, but is not limited to:

(1) mechanical propulsion;

(2) generating sets intended for main propulsion and auxiliary applications;

(3) single engine or multi-engine installations.

1.2 *Definitions*

(1) Certified safe type means electrical equipment that is certified in accordance with the recommendation published by the International Electrotechnical Commission (IEC), in particular publication IEC 60092-502, or with recognized standards at least equivalent. The certification of electrical equipment is to correspond to the category and group for methane gas.

(2) Double block and bleed valves means the set of valves referred to in 16.4.5 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and 1.1.2.10 and 6.2.1.5 of ISC Rules for Ships Using Natural Gas Fuels.

(3) Dual fuel engine ("DF engine") means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

(4) Engine room is a machinery space or enclosure containing gas fuelled engine(s).

(5) Gas means a fluid having a vapour pressure exceeding 0.28MPa absolute at a temperature of 37.8℃.

(6) Gas admission valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the cylinder(s) actual gas demand.

(7) Gas fuel engine means either a gas fuel only engine or a dual fuel engine.

(8) Gas fuel only engine ("GF engine") means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

(9) Gas piping means piping containing gas or air / gas mixtures, including venting pipes.

(10) Gas Valve Unit (GVU) is a set of manual shutoff valves, actuated shut-off and venting valves, gas pressure sensors and transmitters, gas temperature sensors and transmitters, gas pressure control valve and gas filter used to control the gas supply to each gas consumer. It also includes a connection for inert gas purging.

(11) IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (as amended by IMO Resolutions MSC.370(93), MSC.411(97) and MSC.411(99)).

(12) IMO means the International Maritime Organisation.

(13) IGF Code means the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO Resolution MSC.391(95), as amended by IMO Resolution MSC.422(98)).

(14) Low pressure gas means gas with a pressure up to 1.0 MPa.

(15) Lower Heating Value ("LHV") means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.
(16) Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.
Note: Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.
(17) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.
(18) Pre-mixed engine means an engine where gas is supplied in a mixture with air before the turbocharger.
(19) Recognized standards means applicable international or national standards acceptable to ISC or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.
(20) Safety Concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.
Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 *Plans and documents*

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.1, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships:

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of gas system on the engine
(2)	Gas piping system (including double-walled arrangement where applicable)
(3)	Parts for gas admission system②
(4)	Arrangement of explosion relief valves (crankcase①, charge air manifold, exhaust gas manifold) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine (only for DF engine)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for DF engine)
(8)	High pressure parts for pilot fuel oil injection system②(only for DF engine)
(9)	Ignition system (only for GF engine)
Note: ① If required by 9.1.12, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. ② The documentation to contain specification of pressures, pipe dimensions and materials.	

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.2, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships:

No.	Plans and documents
(1)	Safety concept
(2)	Report of the risk analysis①
(3)	Gas specification
(4)	Other plans and documents as deemed necessary by ISC
Note: ① see 1.4 of this Appendix.	

1.4 *Risk analysis*

1.4.1 The risk analysis is to address:
(1) a failure or malfunction of any system or component involved in the gas operation of the engine;
(2) a gas leakage downstream of the gas valve unit;
(3) the safety of the engine in case of emergency shutdown or blackout, when running on gas;
(4) the inter-actions between the gas fuel system and the engine.
Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.
1.4.2 The risk analysis is to be carried out in accordance with international standard ISO 31010: Risk

management - Risk assessment techniques, or other recognized standards.
The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.
1.4.3 The risk analysis is to:
(1) Identify all the possible failures in the concerned equipment and systems which could lead:
① to the presence of gas in components or locations not designed for such purpose, and/or
② to ignition, fire or explosion.
(2) Evaluate the consequences.
(3) Where necessary, identify the failure detection method.
(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.
The results of the risk analysis are to be documented.
1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems
(1) failure of the gas-related systems or components, in particular gas piping and its enclosure, where provided and cylinder gas supply valves. Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the Gas Valve Unit (GVU), are not to be considered in the analysis;
(2) failure of the ignition system (oil fuel pilot injection for DF engines or sparking plugs for GF engines);
(3) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.);
(4) for engines where gas is injected upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots);
(5) failure of the gas combustion or abnormal combustion (misfiring, knocking);
(6) failure of the engine monitoring, control and safety systems;
Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with 9.1.12.2(23) and Note 5, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.
(7) abnormal presence of gas in engine components (e.g. air inlet manifold and exhaust manifold of DF or GF engines) and in the external systems connected to the engines (e.g. exhaust duct);
(8) changes of operating modes for DF engines, including fuel oil mode, gas fuel mode and other working mode;
(9) hazard potential for crankcase fuel gas accumulation, for engines where the space below the piston is in direct communication with the crankcase, refer to 7.2.1.6 of ISC Rules for Ships Using Natural Gas Fuels.

2 *Design Requirements*

2.1 General principles
2.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.
2.1.2 Components containing or likely to contain gas are to be designed to:
(1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked gas in the most severe condition or the fitting of suitable pressure relief devices of an approved type.
Also refer to 7.1.2 and Section 2 of ISC Rules for Ships Using Natural Gas Fuels.
Note:
① Discharge from pressure relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.
② Relief devices are to be fitted with a flame arrester.

2.2 *Design requirements*
2.2.1 For gas carriers, engine-mounted gas piping is to be designed and manufactured in accordance with 5.1 to 5.9 of Chapter 5 and Chapter 16 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the piping is to be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details

etc.) as given in Chapter 3 of ISC Rules for Ships Using Natural Gas Fuels.

2.2.2 Arrangement of the gas piping system on the engine

(1) Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to 9.2.2.1 of ISC Rules for Ships Using Natural Gas Fuels).

(2) The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to 9.2.2.2(6) of ISC Rules for Ships Using Natural Gas Fuels).

(3) For gas carriers, the gas fuel piping system on the engine is to be arranged in accordance with 16.4.3 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the piping is to be arranged in accordance with the principles and requirements of 6.4.1.1 and 6.4.1.2 of ISC Rules for Ships Using Natural Gas Fuels.

The double pipe or duct is to be designed in accordance with 3.3.1.4, 6.4.1.3 and 6.4.1.4 of ISC Rules for Ships Using Natural Gas Fuels.

In case of a ventilated double wall, for gas carriers, the ventilation inlet is to be arranged in accordance with 16.4.3.2 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the ventilation inlet is to be arranged in accordance with 10.6.1.3 of ISC Rules for Ships Using Natural Gas Fuels.

The pipe or duct is to be pressure tested in accordance with 2.7.1, Chapter 2, PART THREE of ISC Rules for Classification of Sea-going Steel Ships to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

(4) Single walled gas piping is only acceptable:

① for engines installed in ESD protected machinery spaces, as defined in 2.3.1.1(2) of ISC Rules for Ships Using Natural Gas Fuels and in compliance with other relevant requirements of ISC Rules for Ships Using Natural Gas Fuels (e.g. 2.3.3);

② in the case as per 6.4.1.2(1) of ISC Rules for Ships Using Natural Gas Fuels.

For gas carriers, the requirements of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply.

In case of gas leakage in an ESD-protected machinery space, which would result in the shutdown of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained. Therefore the safety concept of the engine is to clearly indicate application of the "double wall" or "alternative" arrangement.

Note: The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system on the engine

(1) The charge air system on the engine is to be designed in accordance with 2.1.2 above.

(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).

2.2.4 Exhaust system on the engine

(1) The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.

(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained. Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

2.2.5 Protection of crankcase

(1) Crankcase explosion relief valves are to be installed in accordance with 9.7.4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. Refer also to 7.2.1.6 of ISC Rules for Ships Using Natural Gas Fuels.

(2) For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

2.2.6 With regard to gas ignition in the cylinder, for gas carriers, the requirements of 16.7 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply; for ships other than gas carriers, the requirements of Section 2 of Chapter 7 of ISC Rules for Ships Using Natural Gas Fuels apply.

2.2.7 Control, monitoring, alarm and safety systems

(1) The engine control system is to be independent and separate from the safety system.

(2) The gas supply valves are to be controlled by the engine control system or by the engine gas demand.

(3) Combustion is to be monitored on an individual cylinder basis.

(4) In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in

the conditions specified in 7.2.1.13 of ISC Rules for Ships Using Natural Gas Fuels.
(5) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.
(6) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Table 1 of this Appendix in addition to the general monitoring and safety system functions given by ISC Rules for Classification of Sea-going Steel Ships.
Note: For DF engines, Table 1 applies only to the gas mode.

Monitoring and Safety System Functions for Gas Fuel Engines Table 1

Parameter	Alarm	Automatic activation of the double block-and bleed valves	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the gas fuel supply line	×	×	×	× ⑤
Gas fuel supply systems - malfunction	×	×	×	× ⑤
Pilot fuel injection or spark ignition systems - malfunction	×	× ②	×	× ②⑤
Exhaust gas temperature after each cylinder - high	×	× ②	×	×②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	× ②	×	× ②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	× ②④	× ④	× ②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×
Pressure in the crankcase – high④	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the block and bleed valves	×	×	×	

Symbol: × Applicable
Note:
① DF engine only, when running in gas mode.
② For GF engines, the double block-and-bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.
③ Required only if necessary for the detection of misfiring.
④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.
⑤ GF engine only.
⑥ Where required by 9.7.6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.

2.2.8 Gas admission valves are to be certified safe as follows:
(1) The inside of the valve contains gas and is therefore to be certified for Zone 0.
(2) When the valve is located within a pipe or duct in accordance with 2.2.2(2), the outside of the valve is to be certified for Zone 1.
(3) When the valve is arranged without enclosure in accordance with the "ESD-protected machinery space" (see 2.2.2(4)) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.
However, if they are not rated for the zone they are intended for, it is to be documented that they are suitable for that zone. Documentation and analysis is to be based on IEC 60079-10-1 or IEC 60092-502.

3 *Specific Design Requirements*

3.1 DF Engines

3.1.1 The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas quality. This maximum power available in gas mode and the corresponding conditions are to be stated by the engine manufacturer and demonstrated during the type test. The 110% load tests are not required in the gas mode

of DF engines when 4.1.4, 4.2.1 and 4.3 of this Appendix are implemented in accordance with the provisions in 1.3 of Appendix 4, 2.3 and 3.4 of Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.

3.1.2 DF engines are to be arranged to use either oil fuel or gas fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 *GF Engines*

3.2.1 In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.3 *Pre-Mixed Engines*

3.3.1 Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see 1.4 of this Appendix).

3.3.2 Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

4 *Type Testing, Factory Acceptance Tests and Shipboard Trials*

4.1 Type Testing

4.1.1 Type approval of DF and GF engines is to be carried out in accordance with 9.10.1 and 9.10.2, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, taking into account the additional requirements below.

4.1.2 In addition to the criteria given in 9.1.2.1(1), Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, the type of engine is defined by the following:

(1) gas admission method (direct cylinder injection, charge air space or pre-mixed);

(2) gas supply valve operation (mechanical or electronically controlled);

(3) ignition system (pilot injection, spark ignition, glow plug or gas self-ignition);

(4) ignition system (mechanical or electronically controlled).

4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.

For DF engines, the load tests are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1 of this Appendix).

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It is however to be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 In addition to the measurements and records required in 1.4, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, the following engine data are to be measured and recorded:

(1) Each fuel index for gas and diesel as applicable (or equivalent reading).

(2) Gas pressure and temperature at the inlet of the gas manifold.

(3) Gas concentration in the crankcase.

Additional measurements may be required in connection with the design assessment.

4.1.6 In addition to internal tests required in 2.1, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, the following conditions are to be tested:

(1) DF engines are to run the load points in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type.

(2) For DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.

(3) For DF engines, switch over between gas and diesel modes are to be tested at different loads.

4.1.7 Witnessed tests are to be carried out in accordance with 2.2, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. The following requirements are to be considered:

(1) The following test conditions are to be considered for DF engine during the load test:

① All load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer. This also applies to the overspeed test.

② In case of DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.

(2) The following items are to be carried out for functional test:

① For DF engines, the lowest specified speed is to be verified in diesel mode and gas mode.

② For DF engines, switch over between gas and diesel modes are to be tested at different loads.

③ The efficiency of the ventilation arrangement of the double walled gas piping system is to be verified.

④ Simulation of a gas leakage in way of a cylinder gas supply valve.

Engines intended to produce electrical power are to be tested as follows:

① Capability to take sudden load and loss of load in accordance with the provisions of 9.7.10.1, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.

② For GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in 2.1.1 of this Appendix, the margin for satisfying dynamic load response is to be determined.

Notes:

1. For DF engines, switchover to oil fuel during the test is acceptable.
2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships.

(3) GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with ISC for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;

② Failure of a cylinder gas supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal gas pressure;

⑤ Abnormal gas temperature*.

Note*: This test may be carried out using a simulation signal of the temperature.

4.1.8 Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. The components to be inspected after the test run are to include also:

(1) gas supply valve including pre-chamber as found applicable;

(2) spark igniter (for GF engines);

(3) pilot fuel injection valve (for DF engines).

4.2 *Factory acceptance test*

4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, taking into account the additional requirements below.

For DF engines, the load tests referred to in 2.3, Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1 of this Appendix).

4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 In addition to the records required in 2.2, Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships, the following engine data are to be recorded:

(1) Fuel index, both gas and diesel as applicable (or equivalent reading);

(2) Gas pressure and temperature.

4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Gas fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with ISC for selected cases based on the risk analysis and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), for one cylinder unit;

② Failure of a cylinder gas supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal gas pressure;

⑤ Abnormal gas temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by ISC.

4.3 *Shipboard trials*

4.3.1 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships. For DF engines, the test loads are to be carried out in all operating modes (gas mode, diesel mode, etc.). For DF engines, when load tests specified in 3.4, Appendix 6, Chapter 9, PART THREE of ISC Rules for Classification of Sea-going Steel Ships are carried out in gas mode, test loads are taken as each percentage of the maximum output power in gas mode (see 3.1.1 of this Appendix).

Appendix 2 GUIDELINES FOR ELECTRONICALLY CONTROLLED DIESEL ENGINES

1. General Provisions

1.1 Application

1.1.1 The Guidelines apply to electronically controlled diesel engines.

1.1.2 In addition to the requirements of the Guidelines, electronically controlled diesel engines are to comply with other requirements of this Chapter.

1.1.3 With the advancement of the electronic control technology of diesel engines and the development of intelligent diesel engines, the Guidelines will not limit the progress and development of this new technology.

1.1.4 Where a single electronic control system is used in diesel engines, the applicable requirements of the Guidelines may be referred to.

1.2 *General requirements*

1.2.1 The safety required and functions of electronically controlled diesel engines are not to be inferior to those of non-electronically controlled diesel engines.

1.2.2 The electronic control system is to operate safely and reliably under operating conditions of diesel engines.

1.2.3 The guaranteed working period and the maintenance of the electronic control system are in general to be indicated in product instructions.

1.3 *Definitions*

1.3.1 For the purpose of the Guidelines:

(1) **Electronically controlled diesel engine** means a diesel engine with an electronic control system where system parameters can be adjusted flexibly by control equipment such as ECU to further improve the flexibility and adaptability of individual systems to match the diesel engine, and to optimize its operation and performance.

(2) **Non-electronically controlled diesel engine** means a diesel engine without an electronic control system.

(3) **Intelligent diesel engine** generally means a diesel engine where a comprehensive electronic control is applied to individual systems of fuel oil injection, air intake and exhaust, oil or water cooling, cylinder lubricating, exhaust turbocharging and vibration balance so as to fully optimize system parameters, lower consumption, decrease environmental pollution (low harmful discharge, low noise, low vibration), and automatically monitor its operation and failures.

(4) **Electronic control system of diesel engine:** According to different objects, methods and parameters, an electronic control system of diesel engines has various options and forms, of which the most important is the electronically controlled fuel oil system. It controls parameters such as fuel injection pressure, time, amount and mode. The electronic control system which can flexibly adjust parameters of each system of a diesel engine is called electronic control system of diesel engine, composed of sensors, electronic control units (ECU) and actuators.

(5) **Sensor** means a device or an apparatus which detects ambient conditions, working conditions and various operating parameters of the diesel engine. There are mainly crankshaft speed sensor, pressure sensor, temperature sensor, humidity sensor, gas composition sensor, TDC position sensor, massflow sensor and vibration sensor, which are selected according to electronic control systems of various diesel engines.

(6) **Electronic control unit (ECU)** deals with input information, outputs the results and drives actuators. ECU is mainly composed of a microcomputer, an interface circuit, a drive circuit and necessary software.

(7) **Actuator means a mechanism which** receives control orders from ECU and initiates actions to operate relevant components of the diesel engine. An actuator is mainly composed of an electromagnetic valve, a step motor, electrohydraulic equipment and pipes. The driving power of actuators includes electric power and hydraulic power. Electric drive is operated by the step motor and generally used in cases with less driving power and less strict real-time requirements, such as electronic speed governor, control of variable nozzles of small turbochargers, control of adjustable valves of cooling and lubricating systems. Hydraulic drive is operated by hydraulic power controlled by the electromagnetic valve, such as used in injection systems and air intake and exhaust systems where power transmission is without camshaft.

(8) **Common rail (pressure accumulator)** means a pressure vessel used to supply high pressure fuel oil or

hydraulic oil within the fuel oil or hydraulic oil system of an electronically controlled diesel engine.

2. Design and Installation

2.1 ***Fuel oil and hydraulic oil systems***

2.1.1 Fuel oil and hydraulic oil systems are to comply with the applicable requirements of Chapters 2, 4 and 9 of this PART.

2.1.2 The strength of fuel oil and hydraulic oil pressure accumulators is to comply with the relevant requirements of Chapter 6 of this PART.

2.1.3 For electronically controlled diesel engines intended for single main engine propulsion systems, at least two fuel oil and two hydraulic oil pressure pumps are to be provided for their respective service. The capacity of all pumps are to ensure maximum continuous rating of main propulsion diesel engine, and in case of failure of any one fuel oil and/or hydraulic oil pressure pump, the capacity of other pumps are to ensure that the main propulsion diesel engine can output power necessary for normal navigation. All pumps are to be arranged ready for immediate use. For electronically controlled diesel engines intended for multiple main engines propulsion systems, each diesel engine is at least to be provided with one fuel oil pressure pump and one hydraulic oil pressure pump to ensure maximum continuous rating of diesel engines. One common standby pump connected ready for immediate use is needed, or alternatively, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.

2.1.4 The fuel oil pressure piping between the high pressure fuel oil pumps and the fuel oil injectors is to be protected with a jacketed piping system or other equivalent means capable of preventing fuel oil leakage from splashing onto sources of ignition.

2.1.5 The piping between the high pressure hydraulic oil pumps and the hydraulic actuators is to be protected with a jacketed piping system capable of preventing hydraulic oil leakage from splashing onto sources of ignition.

2.1.6 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the fuel oil and hydraulic oil installations are to be capable of being controlled from readily accessible positions above the working platform.

2.1.7 High pressure fuel oil and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

2.1.8 High pressure fuel oil and high pressure hydraulic oil piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

2.1.9 Equipment fitted for monitoring pressures and temperatures in the high pressure fuel oil and high pressure hydraulic oil systems is to comply with the requirements of ISC Guidelines for Type Approval Test of Electric and Electronic Products in respect to the anticipated vibration and temperature conditions.

2.1.10 In general, dual high pressure fuel oil and high pressure hydraulic oil piping systems are to be provided. Where a fatigue analysis has been carried out (all anticipated pressure, pulsation and vibration loads are to be addressed), single systems may be accepted.

2.1.11 Means are to be provided to prevent continuous injection of fuel oil into cylinders due to failure of control valves.

2.2 Electronic control systems

2.2.1 The design, manufacture and inspection of the electronic equipment used for electronic control systems, including software design, are to comply with the relevant requirements in PART SEVEN of the Rules and ISC Guidelines for Type Approval Test of Electric and Electronic Products.

2.2.2 Electronic control systems are to have the functions of failure self-diagnosis and fail-safe protection. In case of failure, the system is to immediately perform a self-diagnose and initiate appropriate fail-safe protection to maintain operation of the diesel engine.

2.2.3 Those devices in the electronic control system which will affect normal operation of the main propulsion engine in case of functional failure, such as ECUs and crankshaft rotation angle indicators, are to be provided as dual systems. The type and function of such dual systems are to be fully identical. When one system fails, the other will automatically take over so as to maintain normal operation of the engine and an alarm will be given at the same time. For electronically controlled diesel engines intended for ships with two or more main propulsion diesel engines, if risk analysis indicates that in case of failure of electronic control system of any one diesel engine, the others remain capable of outputting power necessary for normal navigation, dual electronic control systems are not necessary for each diesel engine. The electronic control system out of order is to be readily replaced and put into service.

2.2.4 The power for the electronic control system is to be supplied by two independent feeders from two independent power sources.
2.2.5 Local controls and a central control room or bridge control system are to be provided.
2.2.6 The monitoring performed by the electronic control system is to be able to initiate alarms when main functions of sensors, ECUs and actuators fail.
2.2.7 The electronic control system is to be able to monitor the working condition of diesel engines, automatically adjust individual system parameters, and automatically detect and given alarms for failures of systems and components.
2.2.8 Components and parts of the electronic control system are to be changeable considering functional characteristics and structural dimensions, and capable of being disassembled, replaced and installed quickly.
2.2.9 For corrosive materials, anticorrosive coating is to be provided. Where parts made of different metals contact directly each other, means are generally to be provided to prevent electrolytic corrosion.
2.2.10 Electronic control systems are to be provided with test ports to facilitate test and maintenance.

2.3 Failure Mode and Effects Analysis (FMEA)

2.3.1 A Failure Mode and Effects Analysis (FMEA) is to demonstrate that a failure of the functioning of any device or circuit of fuel oil, lubricating oil, hydraulic, starting air, cooling water, and control and safety systems of the electronically controlled diesel engine will not result in the failure or deterioration of the function of other devices or circuits.
2.3.2 An FMEA analysis report is in general to address the following issues:
(1) the standards used for analysis and system design;
(2) the objectives of the analysis;
(3) any assumptions made in the analysis;
(4) the equipment, system or sub-system, mode of operation;
(5) potential failure modes and their causes;
(6) evaluation of the effects of each failure mode;
(7) measures for reducing the risks associated with each failure mode.
2.3.3 Failures of components of the equipment itself need not be taken into account for the analysis.

2.4 Installation

2.4.1 The installation of components of an electronic control system is to comply with the requirements for installation positions on the diesel engine, interface dimension, joints, screening, heat and shock resistance. The components are to be capable of being easily installed and fixed on the diesel engine. The wiring of all electronic circuits is to be secure and reliable to prevent loosening during operation.
2.4.2 When installing components with vibration dampers, sufficient spacing is to be left around to avoid collision with adjacent components or structures.

3 Tests

3.1 General requirements

3.1.1 Electronically controlled diesel engines are to be subjected to type tests, trials at the manufacturer's works and shipboard trials in accordance with the relevant requirements of this Chapter.
3.1.2 For test items related to electronic control systems, refer to the applicable requirements of the Guidelines.

3.2 Type tests

3.2.1 Main components of the electronic control system are to be type tested.
3.2.2 The type test of the electronic control system may also be carried out with the type test of the diesel engine at the same time.
3.2.3 The purpose of the type test of an electronically controlled diesel engine is to confirm normal function of the electronic control system after switch-in. Prior to test, piping, electrical circuits, sensors and actuators of the electronic control system are to be functionally verified and the installation of the system software into each module according to respective downloading instructions is to be confirmed.
3.2.4 Test scope:
(1) functions in respect to safe operation of the diesel engine;
(2) functions which can only be tested together with the diesel engine;
(3) verification of functions of the system software.
3.2.5 The effective functions of an electronic control system are to be verified during tests, generally

including the following items (if applicable):
(1) one crankshaft rotation angle indicator failing;
(2) one control module failing;
(3) one power supply unit failing;
(4) failure of fuel oil injection control valve of one cylinder;
(5) one communication network failing;
(6) main operation panel failing;
(7) earth failure;
(8) failure of action control station;
(9) one stop signal failing;
(10) other applicable failure and function tests.

3.3 Works trials

3.3.1 Prior to test, piping, electrical circuits, sensors and actuators of the electronic control system are to be functionally verified.

3.3.2 During testing of electronically controlled diesel engines, control parameters are to be checked.

3.3.3 The effective functions of an electronic control system are to be verified during tests, generally including the following items (if applicable):
(1) confirmation of software version;
(2) function of fuel oil injection control valve;
(3) function of exhaust control valve;
(4) power supply failure of control module of one cylinder;
(5) function of arrangements for emergency stopping;
(6) one crankshaft rotation angle sensor failing;
(7) other applicable failure and function tests.

3.4 Shipboard trials

3.4.1 Prior to trial, the examination of the items of control and remote control systems of diesel engines in respect to electronic control is to be confirmed.

Appendix 3 APPRAISAL OF CRANKSHAFT STRENGTH OF DIESEL ENGINES

1 General Provisions

1.1 Scope

1.1.1 The calculation methods in this Appendix are to be applied to diesel engines for propulsion and auxiliary purposes, where the engines are capable of continuous operation at their rated power when running at rated speed.

1.1.2 Where the calculation methods in this Appendix cannot be directly used for check in design, detailed design calculations or measurements are to be submitted for approval.

1.1.3 Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted in order to demonstrate equivalence to the calculation methods in this Appendix.

1.2 Requirements for calculation

1.2.1 This Appendix provides two calculation methods, i.e. the Calibration of Crankshaft Fatigue Strength (IACS) in Section 2 and the Calibration of Crankshaft Diameter in Section 3.

1.2.2 Steel crankshafts are to be subjected to the calibration of their fatigue strength in accordance with Section 2 of this Appendix.

1.2.3 Crankshafts, which are made of nodular graphite cast iron or to which Section 2 of this Appendix is not applicable, may be subjected to the calibration of their diameters in accordance with Section 3 of this Appendix.

1.3 Drawings and particulars

1.3.1 Drawings and particulars to be submitted

(1) When the calculation method for crankshaft fatigue strength check (IACS) is adopted, drawings and particulars are to be submitted according to the requirements of Table 1.3.1.

Data Sheet for Calculation of Crankshafts for Diesel Engines Table 1.3.1

1	Engine builder		
2	Engine type designation		
3	Stroke – Cycle ☐2 SCSA ☐4 SCSA		
4	Kind of engine ☐In-line engine ☐V-type engine with adjacent connecting-rods ☐V-type engine with articulated-type connecting-rod ☐V-type engine with forked/inner connecting rod ☐Crosshead engine ☐Trunk piston engine		
5	Combustion method ☐Direct injection ☐Precombustion chamber ☐Others		
6	For designation of cylinders, see Figure 1.3.1(1) of this Appendix		
7	Sense of rotation ☐Clockwise ☐Counterclockwise		
8	Firing order		
9	Firing intervals [deg]		
10	Rated power		kW
11	Rated engine speed		r/min
12	Mean effective pressure		MPa
13	Mean indicated pressure		MPa
14	Maximum cylinder pressure (gauge)		MPa
15	Charge air pressure (gauge, before inlet valves or scavenge ports, whichever applies)		MPa
16	Nominal compression ratio		–
17	Number of cylinders		–
18	Diameter of cylinders		mm

19	Length of piston stroke		mm
20	Length of connecting rod (between bearing centres)		mm
21	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
22	Digitized gas pressure curve presented at equidistant intervals [MPa/crank angle] (intervals not more than 5° CA)		
	Additional Data of V-type Engines		
23	V-angle α. (see Figure 1.3.1(1) of this Appendix)		deg
	For the Cylinder Bank with Articulated-type Connecting Rod (see Figure 1.3.1(2) of this Appendix)		
24	Maximum cylinder pressure (gauge)		MPa
25	Charge air pressure (gauge, before inlet valves or scavenge ports)		MPa
26	Nominal compression ratio		–
27	Articulated-type connecting rod (see Figure 1.3.1(2) of this Appendix)		
28	Distance to link point L_A		mm
29	Link angle a_N		deg
30	Length of connecting rod L_N		mm
31	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
32	Digitized gas pressure curve presented at equidistant intervals [MPa/crank angle] (intervals not more than 5° CA)		
	For the Cylinder Bank with Inner Connecting Rod		
33	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
	Data of Crankshaft (see Figures 2.3.1(1), (2) and 2.4.1(3) of this Appendix) Note: For asymmetric cranks the dimensions are to be entered both for the left and right part of crank throw		
34	Drawing No.		
35	Kind of crankshaft (e.g. solid-forged crankshaft, semi-built crankshaft, etc.)		
36	Method of manufacture (e.g. free form forged, cast steel, etc.)		
37	Heat treatment (e.g. tempered)		
38	Surface treatment of fillets, journals and pins (e.g. nitrided, rolled, etc.)		
39	For crank throw for in-line engine, see Figure 2.3.1(1) of this Appendix For crank throw for engine with 2 adjacent connecting rods, see Figure 2.3.1(2) of this Appendix For crank dimensions necessary for the calculation of stress concentration factors, see Figure 2.4.1(3) of this Appendix		
40	Crankpin diameter D_P		mm
41	Diameter of bore in crankpin D_{BH}		mm
42	Fillet radius of crankpin R_H		mm
43	Recess of crankpin T_H		mm
44	Journal diameter D_G		mm
45	Diameter of bore in journal D_{BG}		mm
46	Fillet radius of journal R_G		mm
47	Recess of journal T_G		mm
48	Web thickness W		mm
49	Web width B		mm
50	Bending length L_1		mm
51	Bending length L_2		mm
52	Bending length L		mm
53	Oil Bore Design ☐Safety margin against fatigue at the oil bores is not less than that acceptable in the fillets		
54	Diameter of oil bore		mm
55	Smallest edge radius of oil bore		mm
56	Surface roughness of oil bore fillet		μm
57	Inclination of oil bore axis related to shaft axis		deg
	Additional Data for Shrink-Fits of Semi-Built Crankshafts		
58	For crank throw of semi-built crankshaft, see Figure 4.1.1 of this Appendix		
59	Shrink diameter D_S		mm
60	Length of shrink-fit L_S		mm
61	Outside diameter of web D_A or twice the minimum distance x mm (the smaller value is to be entered)		mm
62	Amount of shrink-fit (upper and lower tolerances)		mm %
63	Maximum torque (ascertained according to 2.3.3 of this Appendix with consideration of the mean torque)		N·m
	Data of Crankshaft Material Note: Minimum values of mechanical properties of material obtained from longitudinal test specimens		
64	Material designation (according to DIN, AISI, etc.)		
65	Method of material melting process (e.g. open-hearth furnace, electric furnace, etc.)		
66	Tensile strength		MPa
67	Yield strength		MPa

68	Reduction in area at break		%
69	Elongation A_5		%
70	Impact energy – KV		J
71	Young's modulus		MPa
Additional Data for Journals of Semi-Built Crankshafts			
72	Material designation (according to DIN, AISI, etc.)		
73	Tensile strength		MPa
74	Yield strength		MPa
Data According to Calculation of Torsional Stresses Note: In case ISC is entrusted with carrying out a forced vibration calculation to determine the alternating torsional stresses to be expected in the engine and possibly in its shafting, the data according to calculation of torsional vibration are to be submitted			
75	Max. nominal alternating torsional stress (ascertained by means of a harmonic synthesis according to 2.3.3(1) of this Appendix and related to cross-sectional area of bored crank pin)		MPa
76	Engine speed (at which the max. nominal alternating torsional stress occurs)		r/min
77	Minimum engine speed (for which the harmonic synthesis was carried out)		r/min
Data of Stress Concentration Factors (S.C.F.) and/or Fatigue Strength Furnished by Reliable Measurements Note: To be filled in only when data for stress concentration factors and/or fatigue are furnished by the engine manufacturer on the basis of measurements. Full supporting details are to be enclosed.			
78	S.C.F. for bending in crankpin fillet α_B		
79	S.C.F. for torsion in crankpin fillet α_T		
80	S.C.F. for bending in journal fillet β_B		
81	S.C.F. for compressing in journal fillet β_Q		
82	S.C.F. for torsion in journal fillet β_T		
83	Allowable fatigue strength of crankshaft σ_{DW}		MPa

(2) When crankshaft diameter check formula is adopted, only following drawings and particulars are to be submitted for approval:

① crankshaft drawing which must contain all data in respect of the geometrical configuration of the crankshaft;
② type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);
③ two-stroke or four-stroke;
④ direction of rotation (see Figure 1.3.1(1));
⑤ firing order with the respective ignition intervals and V angle (see Figure 1.3.1(1));
⑥ rated power (kW);
⑦ rated speed (r/min);
⑧ mean effective pressure (MPa);
⑨ mean indicated pressure (MPa);
⑩ maximum cylinder pressure (MPa);
⑪ number of cylinders;
⑫ cylinder diameter (mm);
⑬ piston stroke (mm);
⑭ trademark of crank material;
⑮ tensile strength (MPa);
⑯ heat treatment;
⑰ polishing method of fillets and oil holes.

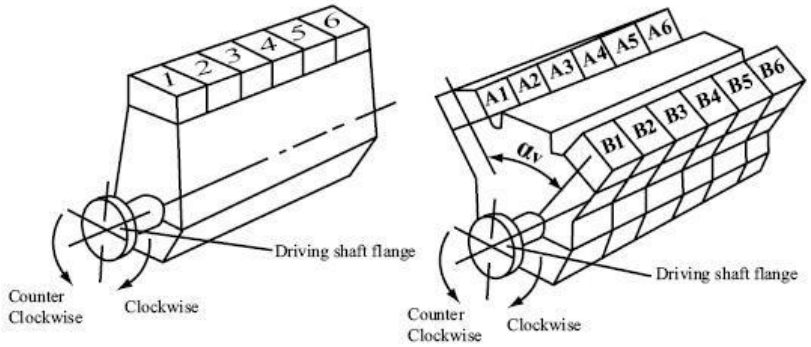


Figure 1.3.1(1) Designation of the Cylinders

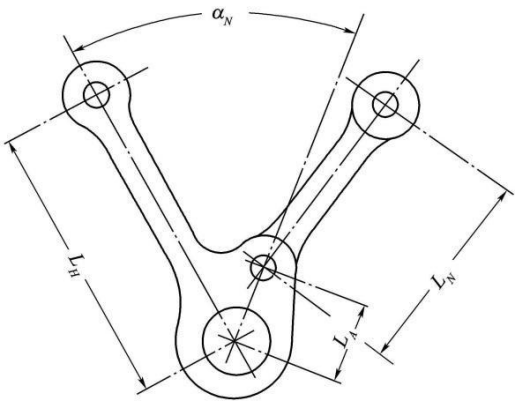


Figure 1.3.1(2) Articulated-Type Connecting Rod

1.3.2 Following particulars are to be submitted for information:
(1) Diesel engine manufacturers are to submit allowable torsional stresses, allowable longitudinal amplitudes (two-stroke), and values of crankshaft deflection regarding compulsory repairs for information.
(2) Diesel engine manufactures are to provide accurate equivalent parameters of torsional and longitudinal vibration and necessary instructions for shafting design and survey.

2 Check of Crankshaft Fatigue Strength (IACS)

2.1 Field of application

2.1.1 This calculation method applies only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings.

2.2 Principles of calculation

2.2.1 The calculation is based on the assumption that the areas exposed to highest stresses are:
(1) fillet transitions between the crankpin and web;
(2) fillet transitions between the journal and web;
(3) outlets of crankpin oil bores.
2.2.2 When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.
2.2.3 Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion, result in an equivalent alternating stress. This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

2.3 Calculation of stresses

2.3.1 Calculation of nominal alternating stresses due to bending moments and radial forces
(1) Calculation of nominal alternating bending stress σ_{BN}
The calculation is based on a statically determined system, composed of one single crank throw supported in the centre of adjacent main journals. The bending length is taken as the length L between the two main bearing midpoints, see Figures 2.3.1(1) and 2.3.1(2) of this Appendix, and the imposed concentrated load is the radial force acting upon the crankpin due to connecting rod force. Radial forces are to be calculated in accordance with gas pressure from single cylinder, oscillating mass of piston mechanism, turning mass of cranks, mass and center of gravity of connecting rods, etc. The connecting rod force is to be obtained from calculation formula of diesel engine power, thus the radial force can be derived from the connecting rod force. At the same time, the maximum radial force F_{Rmax} (radial compression force acting on crank) and the minimum radial force F_{Rmin} (radial tension acting on crank) are to be found in one working cycle, so as to calculate the alternating radial force F_{BR} in one working cycle:

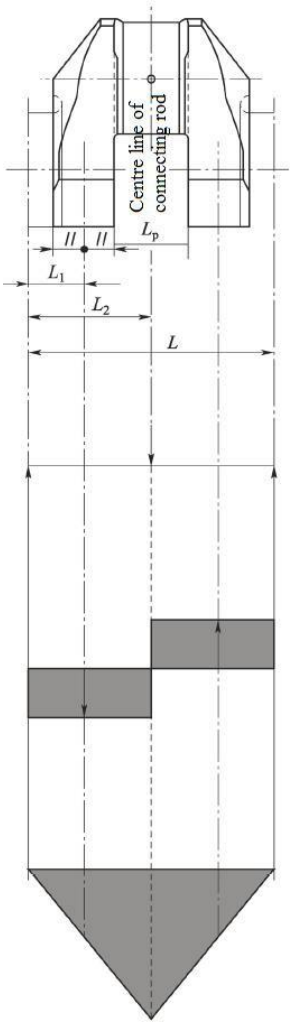


Figure 2.3.1(1)
Crank Throw for in Line Engine

Connecting-rod acting component forces (F_R or F_T)

Radial shear force diagrams (Q_R)

Bending moment diagrams (M_{BR} or M_{BT})

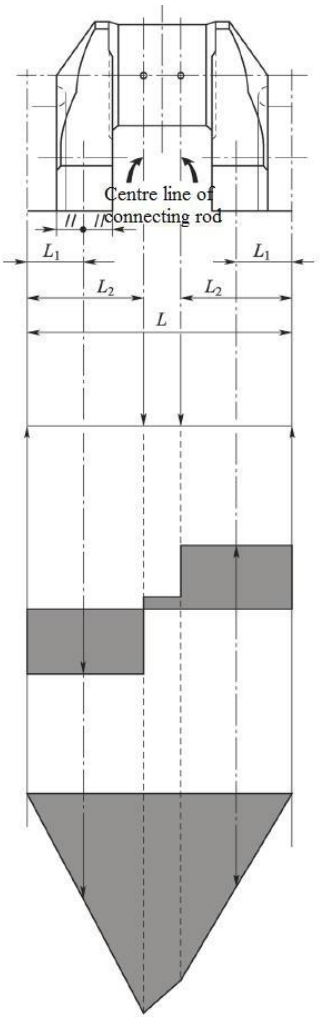


Figure 2.3.1(2)
Crank Throw for Vee Engine with 2 Adjacent Connecting Rods

$$F_{BR} = \pm\frac{1}{2}(F_{Rmax} - F_{Rmin}) \quad \text{N}$$

F_{BR} is the concentrated load of cranks, and its bending moment in way of the centerline of the crank web in the central cross section of crank is the nominal alternating bending moment M_{BN}, the value of which may be obtained by calculating the support reaction at the main bearing. In the case of the crank throw for in-line engines as shown in Figure 2.3.1(1), the support reaction at both main bearings is half the concentrated load F_{BR}, and then the nominal alternating bending moment M_{BN} in way of the centerline (L_1) of the crank web in the central cross section of crank is:

$$M_{BN} = \pm\frac{F_{BR}}{2}L_1 \times 10^{-3} \qquad \text{N·m}$$

The nominal alternating stresses due to bending moments and radial forces are to be related to the cross-sectional area of the crank web, and this cross-sectional area results from the web thickness W and the web width B. Figure 2.3.1(3) of this Appendix shows how W and B are to be measured in respect to overlapped crankshaft or crankshaft without overlap.

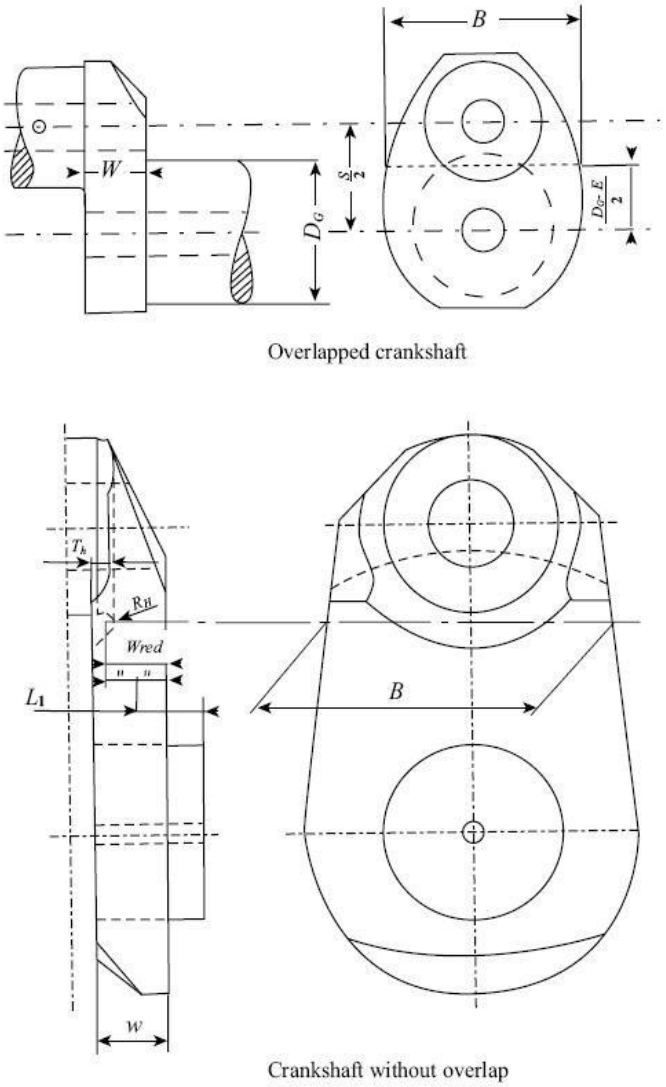


Figure 2.3.1(3) Reference Area of Crank Web Cross Section
(Symbols in the Figure are as defined in Figure 2.4.1(3) of this Appendix)

$$\sigma_{BN} = \pm \frac{M_{BN}}{W_{eq}} K_e \times 10^3 \qquad \text{MPa}$$

where: F_{BR} — alternating radial force, in N;
M_{BN} — nominal alternating bending moment, in N·m
L_1 — distance from main bearing centerline to crank web centerline, in mm, see Figures 2.3.1(1) and (2) of this Appendix;
K_e — empirical factor:
for two-stroke diesel engines $K_e = 0.80$;
for four-stroke diesel engines $K_e = 1.00$;
σ_{BN} — nominal alternating bending stress, in MPa;
$W_{eq} = \frac{BW^2}{6}$ mm^3.

For V-type diesel engines, two connecting rods act upon the same crankpin. The nominal alternating bending moments are to be taken as the bending moments of two triangular bending moments superposed according to phase, the differing designs (adjacent connecting rods, forked connecting rod or articulated-type connecting rod) being taken into account.
Where there are cranks of different geometrical configurations (e.g., asymmetric cranks) in one crankshaft, the calculation is to cover all crank variants.

(2) Calculation of nominal alternating compressive stress σ_{QN}

Radial forces resolved from the thrust of connecting rods are to be obtained in accordance with the simplified calculation method in 2.3.1(1). Radial force calculation table is to be listed in accordance with the formulae of diesel engine power, and a cylinder with maximum radial force value is to be found so as to gain nominal alternating radial force Q_N.

$$Q_N = \pm \frac{1}{2}(Q_{max} - Q_{min}) \quad \text{N}$$

$$\sigma_{QN} = \pm \frac{Q_N}{F} K_e \quad \text{MPa}$$

where: Q_{max} — maximum radial force of relevant cylinder, in N;

Q_{min} — minimum radial force of relevant cylinder, in N;

σ_{QN} — nominal alternating compressive stress due to radial force, in MPa;

$F = BW$, in mm^2.

(3) Calculation of nominal alternating bending stresses σ_{BO} in outlet of crankpin oil bore

The two relevant bending moments M_{BRO} and M_{BTO} are taken in the crankpin cross section through the oil bore (see Figure 2.3.1(4)), and the maximum moment M_{BOmax} and the minimum moment M_{BOmin} acting on the cross section are obtained by the superposition method to further determine the alternating bending moment M_{BON}:

$$M_{BO} = M_{BTO}\cos\psi + M_{BRO}\sin\psi \quad \text{N·m}$$

$$M_{BON} = \pm\frac{1}{2}\left[M_{BO_{max}} - M_{BO_{min}}\right] \quad \text{N·m}$$

where: ψ — angle between oil bore axis and tangential component of the connecting-rod force;

M_{BRO} — bending moment of the radial component of the connecting-rod force, in N·m;

M_{BTO} — bending moment of the tangential component of the connecting-rod force, in N·m.

The alternating bending stress σ_{BON} due to the alternating bending moment M_{BON} is to be related to the cross-sectional area of the axially bored crankpin, i.e.:

$$\sigma_{BON} = \pm\frac{M_{BON}}{W_e} \times 10^3 \quad \text{MPa}$$

The section modulus W_e of the crankpin cross section through the oil bore:

$$W_e = \frac{\pi}{32}\left[\frac{D_P^4 - D_{BH}^4}{D_P}\right] \quad \text{mm}^3$$

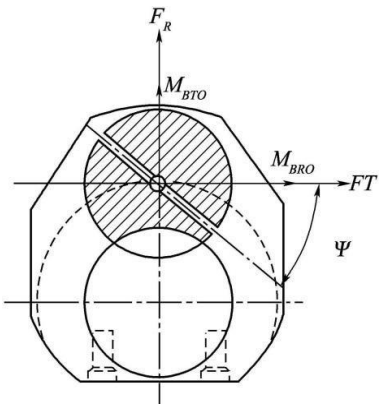


Figure 2.3.1(4) Crankpin section through the oil bore

2.3.2 Calculation of alternating bending stresses

The fillet transitions between the crankpin and web or between the journal and web as well as the outlets of crankpin oil bores are the areas exposed to the highest stresses. With the radial and tangential forces due to gas and inertia loads, the maximum alternating bending stresses will occur in the fillet or oil bore outlet.

(1) The alternating bending stress σ_{BH} in crankpin fillet

$$\sigma_{BH} = \pm(\alpha_B \sigma_{BN}) \quad \text{MPa}$$

where: α_B —stress concentration factor for bending in crankpin fillet (determination – see 2.4 of this Appendix).

(2) The alternating stress σ_{BG} in journal fillet

$$\sigma_{BG} = \pm(\beta_B \sigma_{BN} + \beta_Q \sigma_{QN}) \quad \text{MPa}$$

where: β_B —stress concentration factor for bending in journal fillet (determination n tion factorr for bending);

β_Q —stress concentration factor for compressing in journal fillet (determination – see 2.4 of this Appendix).

(3) The alternating bending stress σ_{BO} in the outlet of crankpin oil bores

$$\sigma_{BO} = \pm(\gamma_B \sigma_{BON}) \quad \text{MPa}$$

where: γ_B — stress concentration factor for bending in crankpin oil bore (determination – see 2.4 of this Appendix).

2.3.3 Calculation of alternating torsional stresses

(1) The calculation for nominal alternating torsional stress τ_N

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to following provisions.

The calculation principle for nominal alternating torsional stresses is that the max. and min. alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for two-stroke cycle engines and from the 0.5th order up to and including the 12th order for four-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavorable conditions, e.g. misfiring in one of the cylinders (misfiring is defined as cylinder condition when no combustion occurs but only compression cycle).

The nominal alternating torque M_T may be determined from above calculation:

$$M_T = \pm \frac{1}{2} (M_{T\max} - M_{T\min}) \quad \text{N·m}$$

Corresponding nominal alternating torsional stress τ_N is to be calculated by the following formula:

$$\tau_N = \pm \frac{M_T}{W_P} \times 10^3 \quad \text{MPa}$$

where: $W_P = \frac{\pi}{16} (\frac{D_P^4 - D_{BH}^4}{D_P})$, or $W_P = \frac{\pi}{16} (\frac{D_G^4 - D_{BG}^4}{D_G})$, mm^3;

$M_{T\max}$, $M_{T\min}$ — maximum and minimum valves of torque, in N·m.

(2) On determination of equivalent alternating stress σ_V, the maximum value gained from the calculation in 2.3.3(1) is to be adopted. Where barred speed ranges are arranged, the maximum value of the nominal alternating torsional stress occurring beyond is to be adopted. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0.8$ of the rated speed for normal firing conditions.

On calculation of crankshaft dimension, in the absence of such a maximum value, τ_N value is to be set as calculation basis. This assumption is based on the installation having the lowest acceptability factor, i.e., the calculation result is to satisfy $Q \geq 1.15$. Therefore, the pre-set τ_N value may be considered as ultimate value of torsional stress of the crankshaft. So far as the whole dynamic apparatus is concerned, provisions of the rules are also to be complied with, through appropriate calculation, so as to ensure that the approved nominal alternating torsional stress is not exceeded. The calculation is to be submitted for examination.

(3) Calculation of alternating torsional stresses τ_H in crankpin fillet:

$$\tau_H = \pm(\alpha_T \tau_N) \quad \text{MPa}$$

where: α_T —stress concentration factor for torsion in crankpin fillet (determination – see 2.4 of this Appendix).

(4) The calculation of alternating torsional stress τ_G in journal fillet:

$$\tau_G = \pm (\beta_T \tau_N) \quad \text{MPa}$$

where: β_T — stress concentration factor for torsion in journal fillet (determination – see 2.4 of this Appendix).

$$\sigma_{TO} = \pm(\gamma_T \tau_N) \quad \text{MPa}$$

(5) The calculation of alternating torsional stress σ_{TO} in crankpin oil bore:

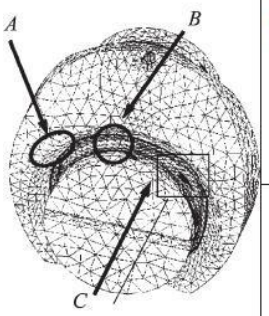
where: γ_T — stress concentration factor for torsion in outlet of crankpin oil bore (determination – see 2.4 of this Appendix).

2.4 Calculation of stress concentration factors

2.4.1 General requirements

(1) The stress concentration factors for bending (α_B, β_B) is defined as the ratio of the maximum bending stress occurring in the fillets under bending load acting in the central cross section of a crank to the nominal stress related to the web cross section (see Figure 2.4.1(1)).
The nominal stress is to be determined under the bending moment in the middle of the solid web.
(2) The stress concentration factor for torsion (α_T, β_T) is defined as the ratio of the maximum torsional stress – occurring under torsional load in the fillets – to the nominal stress related to the bored crankpin or journal cross-section (see Figure 2.4.1(1)).
(3) The stress concentration factor for compressing (β_Q) is defined as the ratio of the maximum compressive stress – occurring in the journal fillet under bending load – to the nominal compressive stress related to the web cross section.
(4) The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress – occurring at the outlet of the crankpin oil bore under bending and torsional loads – to the corresponding nominal stress related to the axially bored crankpin cross section (see Figure 2.4.1(2)).
(5) The stress concentration factors may be evaluated by means of the formulae in accordance with 2.4.2, 2.4.3 and 2.4.4 of this Appendix applicable to the fillets and crankpin oil bores of solid-forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. Stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil bore.
(6) Where there are reliable measurement and/or calculation methods, direct assessment of Stress Concentration Factor (SCF) may be carried out, and relevant documents and analysis methods are to be submitted to ISC to prove that the adopted SCF calculation method is equivalent to the existing rule requirements. Where the geometry of crankshafts is outside the boundaries as specified in 2.4.1(8), (9) and (10), the stress concentration factors may be calculated by the method as specified in 2.4.5 and Annex III of this Appendix.
(7) All crank dimensions necessary for the calculation of stress concentration factors are shown in Figure 2.4.1(3).

Definition of Stress Concentration Factors in Crankshaft Fillets



	Stress	Max$\|\sigma_3\|$	Maxσ_1	
Torsional loading	Location of maximal stresses	*A*	*C*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	τ, σ; σ_3 σ_2 σ_1; $\|\sigma_3\| > \sigma_1$	τ, σ; σ_3 σ_2 σ_1; $\sigma_1 > \|\sigma_3\|$	τ, σ; σ_3 σ_2 σ_1; $\sigma_1 \approx \|\sigma_3\|$
	Equivalent stress and S.C.F	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ S.C.F.$= \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_T		
Bending loading	Location of maximal stresses	*B*	*B*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$	τ, σ; σ_3 σ_2 σ_1; $\sigma_2 \neq 0$		
	Equivalent stress and S.C.F	$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}$ S.C.F.$= \frac{\sigma_{equiv}}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

Figure 2.4.1(1) Stress Concentration Factors in Crankshaft Fillets

Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings

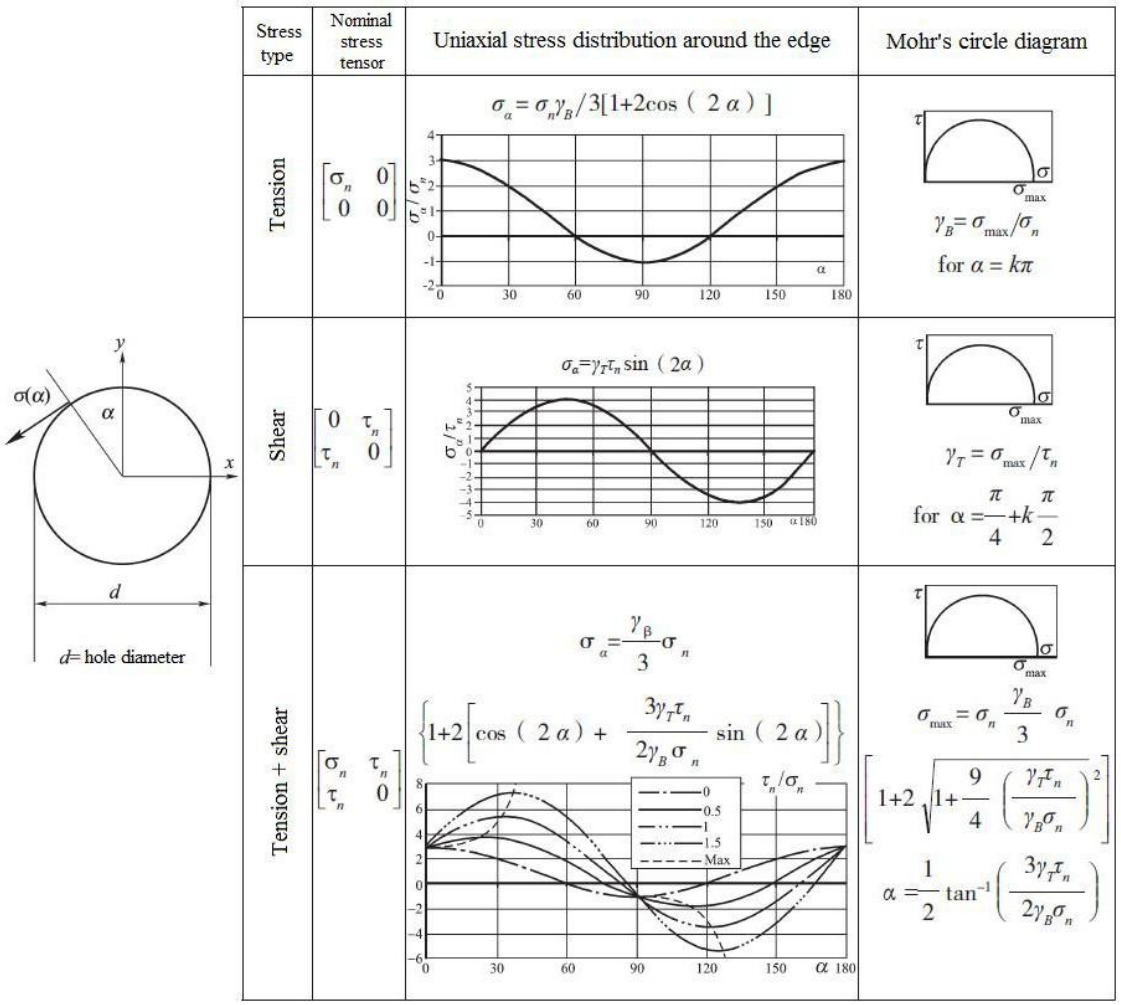


Figure 2.4.1(2) Stress Concentration Factors and Stress Distribution of Oil Drillings

Actual dimensions in the Figure:

D_P — crankpin diameter, in mm;

D_{BH} — diameter of bore in crankpin, in mm;

D_O — diameter of oil bore in crankpin, in mm;

R_H — fillet radius of crankpin, in mm;

T_H — recess of crankpin, in mm;

D_G — journal diameter, in mm;

D_{BG} — diameter of bore in journal, in mm;

R_G — fillet radius of journal, in mm;

T_G — recess of journal, in mm;

S — piston stroke, in mm;

E — journal overlap, $E = \frac{D_P + D_G}{2} - \frac{S}{2}$, in mm;

W — web thickness, in mm; in the case of 2 stroke semi-built crankshafts without journal overlap and when $T_H > R_H$, the web thickness must be considered as equal to $W_{red} = W - (T_H - R_H)$ (refer to Figure 2.3.1(3) of this Appendix);

B — web width, in mm; in the case of 2 stroke semi-built crankshafts without journal overlap, web width B is to be taken in way of crankpin fillet radius centre (refer to Figure 2.3.1(3) of this Appendix).

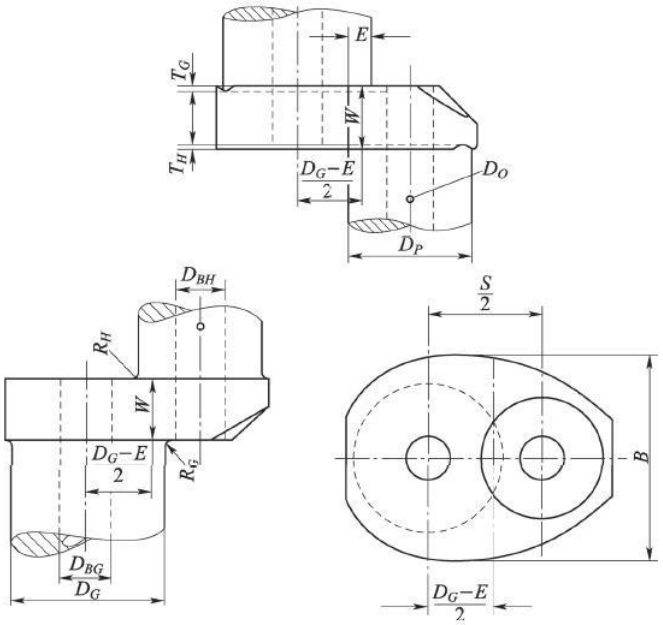


Figure 2.4.1(3)

Crank Dimensions Necessary for the Calculation of Stress Concentration Factors in Crank Throws

(8) The following related dimensions in Table 2.4.1 will be applied for the calculation of stress concentration factors.

(9) Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

$$e \leq 0.5$$
$$0.2 \leq w \leq 0.8$$
$$1.1 \leq b \leq 2.2$$
$$0.03 \leq r \leq 0.13$$
$$0 \leq d_G \leq 0.8$$
$$0 \leq d_H \leq 0.8$$
$$0 \leq d_O \leq 0.2$$

(10) Low range of e can be extended down to large negative values provided that:

a. If calculated f (rec) < 1 then the factor f (rec) is not to be considered (f (rec) = 1);

b. If e < -0.5 then f (e, w) and f (r, e) are to be evaluated replacing actual value of e by -0.5.

Table 2.4.1

Crankpin fillet	Journal fillet
$r = R_H/D_P$	$r = R_G/D_P$
$e = E/D_P$	
w① $= W/D_P$	
$b = B/D_P$	
$d_O = D_o/D_P$	
$d_G = D_{BG}/D_P$	
$d_H = D_{BH}/D_P$	
$t_H = T_H/D_P$	
$t_G = T_G/D_P$	

Note: ① This applies to crankshafts with overlap. For crankshafts without overlap, $w = W_{red}/D_P$.

2.4.2 Calculation of the stress concentration factor for crankpin

(1) The stress concentration factor α_B for bending:

$$\alpha_B = 2.6914 f(e,w) f(w) f(b) f(r) f(d_G) f(d_H) f(rec)$$

where:

$$f(e,w) = -4.1883 + 29.2004w - 77.5925w^2 + 91.9454w^3 - 40.0416w^4 + (1-e)(9.544 - 58.348w + 159.3415w^2 - 192.5846w^3 + 85.2916w^4) - (1-e)^2(3.8399 - 25.0444w + 70.5571w^2 - 87.0328w^3 + 39.1832w^4);$$

$$f(w) = 2.179w^{0.7171};$$

$$f(b) = 0.684 - 0.0077b + 0.1473b^2;$$

$$f(r) = 0.2081r^{-0.5231};$$

$$f(d_G) = 0.9993 + 0.27d_G - 1.0211d_G^2 + 0.5306d_G^3;$$

$$f(d_H) = 0.9978 + 0.3145d_H - 1.5241d_H^2 + 2.4147d_H^3;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(2) Stress concentration factor α_T for torsion:

$$\alpha_T = 0.8 f(r,e) f(b) f(w)$$

where: $f(r,e) = r^{-(0.2205+0.1015e)}$;

$$f(b) = 7.8955 - 10.654b + 5.3482b^2 - 0.857b^3;$$

$$f(w) = w^{-0.145}.$$

2.4.3 Calculation of stress concentration factor for journal

(1) The stress concentration factor β_B for bending:

$$\beta_B = 2.7146 f_B(e,w) f_B(w) f_B(b) f_B(r) f_B(d_G) f_B(d_H) f(rec)$$

where:

$$f_B(e,w) = -1.7625 + 2.9821w - 1.5276w^2 + (1-e)(5.1169 - 5.8089w + 3.1391w^2) + (1-e)^2(-2.1567 + 2.3297w - 1.2952w^2);$$

$$f_B(w) = 2.2422w^{0.7548};$$

$$f_B(b) = 0.5616 + 0.1197b + 0.1176b^2;$$

$$f_B(r) = 0.1908r^{-0.5568};$$

$$f_B(d_G) = 1.0012 - 0.6441d_G + 1.2265d_G^2;$$

$$f_B(d_H) = 1.0022 - 0.1903d_H + 0.0073d_H^2;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(2) The stress concentration factor β_Q for compressing:

$$\beta_Q = 3.0128 f_Q(e) f_Q(w) f_Q(b) f_Q(r) f_Q(d_H) f_Q(rec)$$

where: $f_Q(e) = 0.4368 + 2.163(1-e) - 1.5212$（1-$e$）^{2};

$$f_Q(w) = \frac{w}{0.0637 + 0.9369w};$$

$$f_Q(b) = b - 0.5;$$

$$f_Q(r) = 0.5331r^{-0.2038};$$

$$f_Q(d_H) = 0.9937 - 1.1949d_H + 1.7373d_H^2;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(3) The stress concentration factor β_T for torsion:

If the diameters and fillet radii of crankpin and journal are the same:

$$\beta_T = \alpha_T$$

If crankpin and journal diameters and/or radii are of different sizes:

$$\beta_T = 0.8 f(r,e) f(b) f(w)$$

For $f(r, e)$, $f(b)$, $f(w)$, see the calculation of α_T, however, the radius of the journal fillet is to be related to the journal diameter:

$$r = \frac{R_G}{D_G}$$

2.4.4 Calculation of stress concentration factor for outlet of crankpin oil bore

(1) The stress concentration factor γ_B for bending:

$$\gamma_B = 3 - 5.88 d_O + 34.6 d_O^{\ 2}$$

(2) The stress concentration factor γ_T for torsion:

$$\gamma_T = 4 - 6 d_O + 30 d_O^{\ 2}$$

2.4.5 Calculation of stress concentration factors by means of finite element method

(1) General requirements

The formulae for the calculation of Stress Concentration Factors (SCF) in the crankshaft fillets as specified in 2.4.2, 2.4.3 and 2.4.4 of this Appendix are based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of the formulae is limited to those geometries. Where the geometry of crankshafts is outside the boundaries as specified in 2.4.1(8) and (9), the SCF may be obtained as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method in this Appendix or the alternative methods, equivalent stresses are to be calculated for bending and principal stresses for torsion.

The procedure as well as evaluation guidelines of this Section are valid for both solid cranks and semi-built cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

Prior to FE analysis, it is advised to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

(2) Model requirements

The basic requirements for building the FE-model are presented in ① below. The material properties required for FE analysis are given in ② below. The FE-model is to comply with the element mesh quality criteria as specified in ③ below.

① Element mesh requirements

In order to fulfil the mesh quality criteria, the FE model is to be constructed in accordance with the following requirements:

—The FE model consists of one complete crank, from the main bearing centerline to the opposite side main bearing centerline.

—Element types used in the vicinity of the fillets include 10 node tetrahedral elements, 8 node hexahedral elements and 20 node hexahedral elements.

—Mesh properties in fillet radii and the element mesh of ±90° in circumferential direction from the crank plane are to comply with the following requirements:

- Maximum element size $a = r/4$ through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to $5a$ (where r is fillet radius). In the case of multi-radii fillet r is the local fillet radius. (If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.)
- Recommended manner for element size in fillet depth direction is as follows: first layer thickness equal to element size of a; second layer thickness equal to element to size of $2a$; third layer thickness equal to element to size of $3a$.
- Minimum 6 elements across web thickness.

—Generally the rest of the crank is to be suitable for numeric stability of the solver.

—Counterweights have to be modeled only when influencing the global stiffness of the crank significantly.

—Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than $2r$, see Figure 2.4.5(1).

—Drillings and holes for weight reduction have to be modeled.

—Sub-modeling may be used as far as the software requirements are fulfilled.

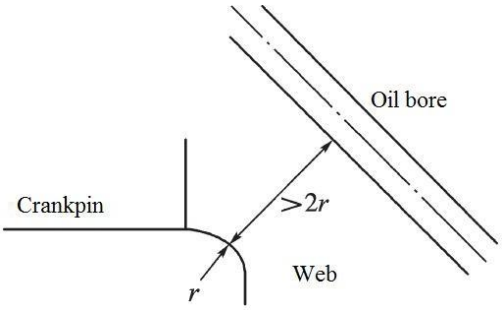


Figure 2.4.5(1) Oil Bore Proximity to Fillet

② Material

In FE analysis, the material properties such as Young's Modulus (E) and Poisson's ratio (ν) are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel the following Young's Modulus (E) and Poisson's ratio (ν) are advised:

$E = 2.05 \cdot 10^5$ MPa

$\nu = 0.3$.

③ Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

—Principal stresses criterion

The quality of the mesh is to be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress is to be zero. With principal stresses σ_1, σ_2 and σ_3 the following criterion is required:

$$\min\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right) < 0.03 \max\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right)$$

—Averaged/unaveraged stresses criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF. unaveraged nodal stress results calculated from each element connected to a node$_i$ should differ less than by 5 % from the 100 % averaged nodal stress results at this node$_i$ at the examined location.

(3) Load cases

The following load cases are to be considered when stress concentration factors are calculated by FEM.

① Torsion

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded pure torsion. In the model surface warp at the end faces is suppressed. Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face (see Figure 2.4.5(2)).

Boundary and load conditions as shown in Figure 2.4.5(2) are valid for both in-line and V-type engines.

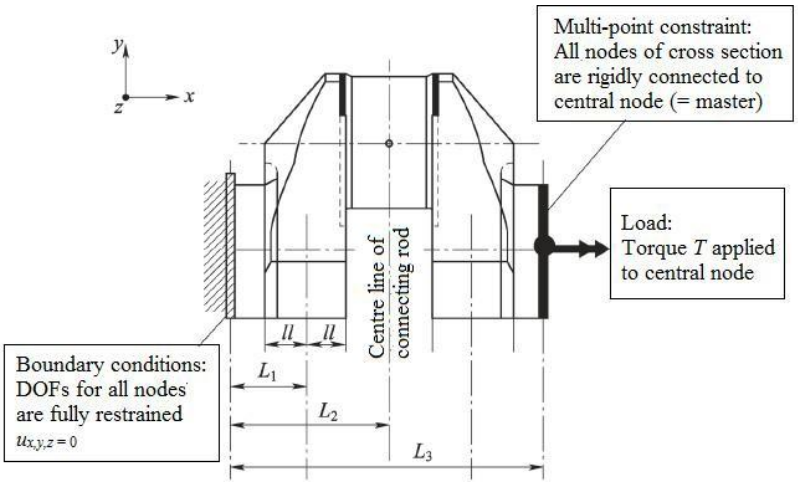


Figure 2.4.5(2) Boundary and Load Conditions for the Torsion Load Case

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress τ_{equiv} is calculated in accordance with the following formula:

$$\tau_{equiv} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2}\right) \quad \text{MPa}$$

The maximum value taken for the subsequent calculation of the stress concentration factors α_T and β_T in the crank pin and journal fillet respectively as follows:

$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{equiv,\phi}}{\tau_N}$$

where: τ_N—nominal torsional stress calculated in accordance with 2.3.3, in MPa;

$\tau_{equiv,\alpha}, \tau_{equiv,\beta}$—maximum equivalent torsional stress in the crank pin and journal fillet, in MPa.

② Pure bending

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded in pure bending. In the model surface warp at the end faces is suppressed. The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face (see Figure 2.4.5(3)).

Boundary and load conditions as shown in Figure 2.4.5(3) are valid for both in-line and V-type engines.

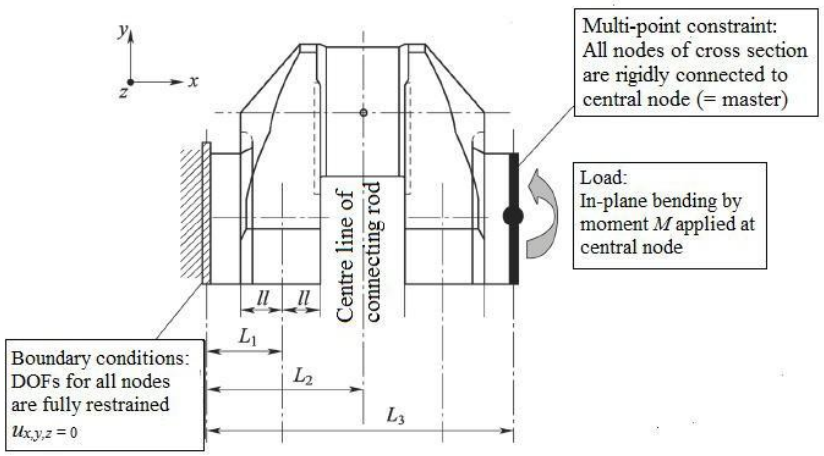


Figure 2.4.5(3) Boundary and Load Conditions for the Pure Bending Load Case

For all nodes in both the journal and pin fillet, the equivalent stresses are extracted. The maximum value is used to calculate the stress concentration factors α_B and β_B according to the following formulae:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_{BN}}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_{BN}}$$

where: σ_{BN} —nominal alternating bending stress calculated in accordance with 2.3.1(1), in MPa;

$\sigma_{equiv,\alpha}, \sigma_{equiv,\beta}$—maximum equivalent stress in the crank pin and journal fillet, in MPa.

③ Bending with shear force

This load case is calculated to determine the stress concentration factor for compressive stress β_Q for the journal fillet.

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is suppressed. All nodes are connected rigidly to the centre node; boundary conditions are applied to the centre nodes. These nodes act as master nodes with 6 degrees of freedom. The force is applied to the central node located at the pin centre-line of the connecting rod (see Figure 2.4.5(5)). This node is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions as shown in Figure 2.4.5(4) are valid for in-line and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

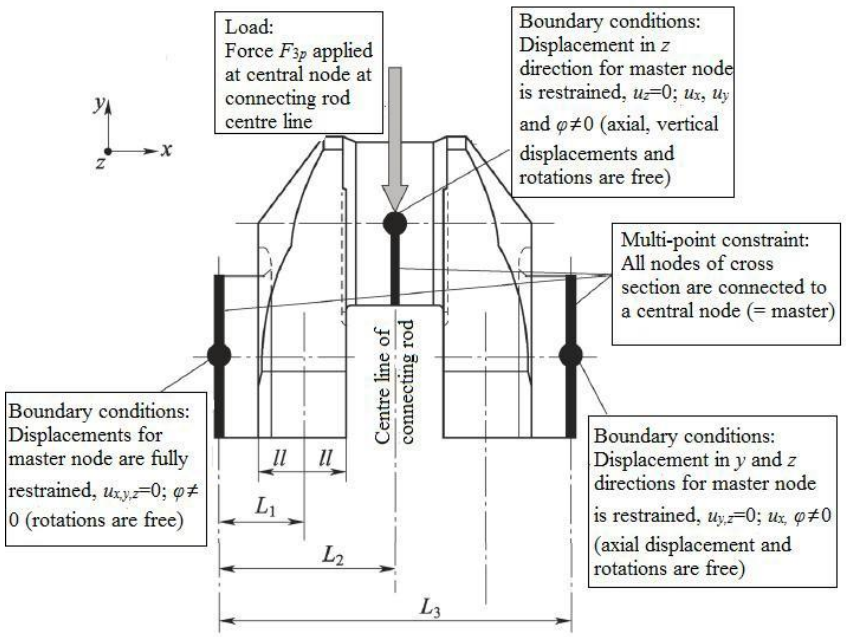


Figure 2.4.5(4) Boundary and Load Conditions for the 3-point Bending Load Case of an In-line Engine

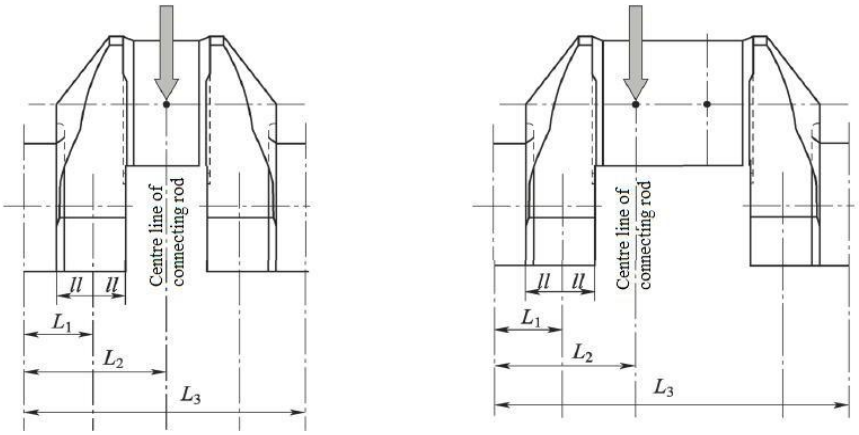


Figure 2.4.5(5) Load Applications for In-line and V-type Engines

The maximum equivalent stress σ_{3P} in the journal fillet is evaluated. The stress concentration factors in the journal fillet can be determined in two ways as shown below.

— Method 1. This method is analogue to the FVV investigation. The results from pure bending and bending with shear force in the journal fillet are combined as follows:

$$\sigma_{3P} = \beta_B \sigma_{N3P} + \beta_Q \sigma_{Q3P} \quad \text{MPa}$$

The stress concentration factor β_Q is calculated as follows:

$$\beta_Q = \frac{\sigma_{3P} - \beta_B \sigma_{N3P}}{\sigma_{Q3P}}$$

where: σ_{3P} — maximum equivalent stress as found by the FE calculation, in MPa;

σ_{N3P} — nominal bending stress in the web centre due to the force F_{3P} applied to the centre-line of the actual connecting rod, in MPa, see Figure 2.4.5(5);

β_B — stress concentration factor for bending in the journal fillet under pure bending load, as determined in 2.4.5(3)②;

σ_{Q3P} — nominal compressive stress due to radial (shear) force Q_{3P} in the web due to the force F_{3P} applied to the centre-line of the actual connecting rod, in MPa (see Figures 2.1.3(1) and (2)). $\sigma_{Q3P} = Q_{3P}/(BW)$, where B and W are web width and thickness respectively.

— Method 2. This method is not analogous to the FVV investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet stress concentration factor β_{BQ} can be found directly by the 3-point bending FE calculation.

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

For symbols see Method 1.

When using Method 2 the radial force and stress becomes superfluous. The alternating bending stress σ_{BG} in the journal fillet as per 2.3.2(2) is calculated in accordance with the following formula:

$$\sigma_{BG} = \pm \left| \beta_{BQ} \sigma_{BN} \right|$$

Note that the use of Method 2 does not apply to the crankpin fillet and that this SCF must not be used in connection with calculation methods other than those assuming a statically determined system as in this Appendix.

2.5 Determination of additional bending stresses σ_{add}

2.5.1 In addition to the alternating bending stresses in fillets caused by gas and inertia loads, additional bending stresses σ_{add} (additional bending stress σ_{aa} due to misalignment and bedplate deformation as well as

additional bending stress σ_{ax} due to axial vibrations) will cause crankshaft fatigue damage unless restriction is imposed or accurate determination made.
Additional bending stresses are as given in Table 2.5.1 to different engine types:

Table 2.5.1

Type of engine	σ_{add} (MPa)
Crosshead engines	± 30①
Trunk piston engines	± 10

Note: ① The additional stress of ±30 MPa is composed of two components: an additional stress of ±20 MPa resulting from axial vibration, an additional stress of ±10 MPa resulting from misalignment/bedplate deformation. It is recommended that a value of ±20 MPa be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

2.5.2 According to the calculation, the appraisal of the crankshaft is based on the minimum acceptability factor Q (see 2.8 of this Appendix). Therefore, where $Q > 1.15$ with a certain margin, the allowable amplitude of axial vibrations may be raised corresponding to the maximum value of the allowable crankshaft deflection provided by the diesel engine manufacturer.

2.6 Calculation of equivalent alternating stress σ_v

2.6.1 For calculation of equivalent alternating stress σ_v in fillets, the theory of constant energy of distortion is to be used. In this case, it is assumed that the maximum alternating bending stresses and maximum alternating torsional stresses within a crankshaft occur simultaneously and at the same point.
At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased (see Figure 2.4.1(2) of this Appendix).

2.6.2 Equivalent alternating stress

The equivalent alternating stress σ_v is calculated in accordance with the formulae given.

For the crankpin fillet:

$$\sigma_v = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H^2} \quad \text{MPa}$$

For the journal fillet:

$$\sigma_v = \quad t\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G^2} \quad \text{MPa}$$

For crankpin oil bore outlet:

$$\sigma_v = \pm\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right] \quad \text{MPa}$$

For other parameters, see 2.3 of this Appendix.

2.7 Calculation of fatigue strength

2.7.1 The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets. Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the allowable fatigue strength σ_{DW} may be

Related to the crankpin diameter:

$$\sigma_{DW} = \pm K(0.42R_m + 39.3)\left[0.264 + 1.073D_P^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_x}}\right] \quad \text{MPa}$$

with $R_x = R_H$ in the fillet area; $R_x = D_O/2$ in the oil bore area.

Related to the journal diameter:

$$\sigma_{DW} = \pm K(0.42R_m + 39.3)\left[0.264 + 1.073D_G^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_G}}\right] \quad \text{MPa}$$

evaluated by means of the following formulae:

where: K — factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area:

= 1.05 for continuous grain flow forged or drop-forged crankshafts;
= 1.0 for free form forged crankshafts (without continuous grain flow);
= 0.93 for cast steel crankshafts (factor for cast steel crankshafts with cold rolling treatment in fillet area, using a ISC approved cold rolling process);

R_m — tensile strength of crankshaft material, in MPa.

For other parameters, see 2.4.1 of this Appendix.

These formulae are subject to the following conditions:

(1) surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1.5 times the oil bore diameter) are to be smoothly finished;

(2) for calculation purposes RH, RG or Rx are to be taken as not less than 2 mm.

2.7.2 When a surface treatment process is applied, it is to be approved by ISC. The fatigue strength of fillets and outlets of oil bores that have been surface treated may be calculated according to the method specified in Annex II of this Appendix.

2.7.3 As an alternative, the fatigue strength of the crankshaft can be determined by experiment based either on full size crank throw (or crankshaft) or on specimens taken from a full size crank throw. The result of the fatigue test is to be evaluated according to the method specified in Annex I of this Appendix.

2.8 Acceptability criteria of a crankshaft

2.8.1 The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison through the acceptability factor Q is to be carried out for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore and is based on the formula:

$$Q = \frac{\sigma_{DW}}{\sigma_V} \geq 1.15$$

2.8.2 The acceptability factor Q is not necessarily the safety factor of the crankshaft. It only stands for a value related to the calculation. The value of fatigue strength of the material is not the only cause for the damage of the crankshaft, which actually has something to do with the strained condition of the crankshaft. Where the crankshaft is excessively deformed, its reliability will be affected. However, the acceptability factor Q can also show the safety margin of the crankshaft itself, for the calculation is based on its torsional stress for appraisal of the crankshaft, combined with the bending stress concerned, so as to get the minimum acceptability factor. Therefore, where $Q > 1.15$ with a certain margin, the allowable values of torsional stress, axial vibration stress, crankshaft deflection regarding compulsory repairs are to be appropriately adjusted. This is useful to design, operation and survey.

2.9 Allowable values to be provided by manufacturers

2.9.1 Manufacturers are to provide the values of allowable torsional stresses, allowable axial amplitudes and crankshaft deflection regarding compulsory repairs.

2.9.2 The allowable values mentioned in 2.9.1 of this Appendix are to be taken as the relevant values on calculating Q in 2.8.1 of this Appendix, or to be taken as the limiting values concerned when $Q = 1.15$.

3 Calibration of Crankshaft Diameter

3.1 Scope

3.1.1 The calculation is applicable to crankshafts of in-line and V-diesel engines. These crankshafts have an equal span of bearings adjacent to cranks, and are made of forged steel, cast steel, alloy steel or nodular graphite cast iron.

3.2 Calculation principles

3.2.1 The calculation is also based on the assumption that the fillet transitions between the journal and web are the crankshaft areas to the highest stresses. It is the most concentrated stress area and the fatigue damage of the crankshafts is most probably to happen here.

3.2.2 Crankshaft strength calibration is based on the theory of maximum normal stress. This calculation is assuming that the damage of crankshaft is due to the combined action of the maximum bending moment (bending stress) and maximum torque (shearing stress) upon it. Therefore, the maximum bending moment and the maximum torque (multiplying relevant stress concentration factors) are to be combined to the maximum equivalent bending moment. By fatigue strength of material and adequate safety factors, the calculation formula of the minimum diameter necessary for the crankshafts can be inferred.

3.3 Calculation of the minimum diameter of the crankshafts

3.3.1 The specified tensile strength of forgings and castings for crankshafts is in general to be selected within the following scope and in compliance with the relevant requirements of ISC Rules for Materials and Welding.

(1) Carbon and carbon-manganese steel 400 to 600 MPa;
(2) Alloy steel 600 to 1,000 MPa;
(3) Nodular graphite cast iron 490 to 780 MPa.

3.3.2 The minimum diameter D_P (or D_G) of the crankpins or the journals of fully-built or semi-built crankshafts is to be calculated by the following.

For crankshafts made of forged steel, cast steel and alloy steel:

$$D_P = \sqrt[3]{\frac{D^2\left[Aa_B p_z (L - L_p) + Ca_T p_i S\right]}{65 \times (\frac{R_m + 160}{560})}} \quad \text{mm}$$

For crankshafts made of nodular graphite cast iron:

$$D_P = \sqrt[3]{\frac{D^2\left[Aa_B p_z (L - L_p) + Ca_T p_i S\right]}{59 \times (0.3 + \frac{0.7R_m}{490})}} \quad \text{mm}$$

where: D — cylinder diameter, in mm;
S — piston stroke, in mm;
L — span of adjacent bearings measured from center to center, in mm;
L_P — length of crankpin, in mm;
p_z — maximum combustion pressure, in MPa;
p_i — mean indicated pressure, in MPa;
R_m — tensile strength of the material used, in MPa;
A — coefficient:
for single acting in-line diesel engines, A = 0.50;
for two-stroke V-diesel engines, A is to be selected in accordance with Table 3.3.2(1);
for four-stroke V-diesel engines, A is to be selected in accordance with Table 3.3.2(2);
C — coefficient:
for single acting in-line diesel engines, C is to be selected in accordance with Table 3.3.2(3);
for two-stroke V-diesel engines, C is to be selected in accordance with Table 3.3.2(4);
for four-stroke V-diesel engines, C is to be selected in accordance with Table 3.3.2(5);
α_B — bending stress concentration factor;
α_T — torsional stress concentration factor.

3.3.3 Calculation and application of stress concentration factor

(1) Fracture of the diesel engine crankshafts is most probably caused by fatigue. When in bending fracture, fatigue appears mostly in the transition fillets between the crankpin and web or between journal and web. This is because the stress here is most concentrated. Therefore, the so called bending stress concentration factor means the ratio of the maximum bending stress occurring in the transition fillets of the crankpins under bending load acting in the central cross-section of a crank to the nominal bending stress related to the crankpin cross-section. The nominal bending stress is to be determined under the bending moment in the middle of the solid web.

(2) Torsional stress concentration factor means the ratio of the maximum torsional stress under the torsional load in the fillets to the nominal torsional stress related to the crankpin cross-section.

(3) Fatigue damage of the crankshafts is related to the actual stress in the transition fillets acted by the operation of the diesel engines. The actual stresses include the additional stress caused by misalignment of the crankshafts and highly concentrated stress caused by the geometry of the crankshafts. Therefore, bending stress concentration factor is actually the surface features of this ingredient, which is obtained through quantitative study of three-directional photoelasticity test.

(4) The geometrical dimensions of the crankshafts affecting the stress concentration in fillets mainly include the radius of transition fillets R_H, web thickness W, web breadth B (for taking B, see Figure 2.3.1(1) of this Appendix), journal overlap E, diameter of journal cavity D_{BH}, recess depth of fillet T_H, etc., which are more or less affecting. Anyhow, to improve the applicability of stress concentration factor, the geometrical dimensions mentioned above corresponding to crankpin diameter D_P (or fillet radius R_H) turn to dimensionless relative dimension, i.e.:

$$r = R_H / D_P$$

$$w = W / D_P$$
$$b = B / D_P$$
$$e_k = 1 - E / D_P$$
$$d_H = D_{BH} / D_P$$
$$\delta = T_H / R_H$$

Only when the relative dimensions mentioned above are used in a specified range can the stress concentration factor be effective, and they are only applicable to the crankpins of fully-built or semi-built crankshafts. The applicable range of the relative dimensions is as follows:

$$0.03 \le r \le 0.10$$
$$0.25 \le w \le 0.60$$
$$1.30 \le b \le 2.00$$
$$0.50 \le e_k \le 1.50$$
$$0 \le d_H \le 0.70$$
$$0 \le \delta \le 0.65$$

The dimensions for the calculation of the stress concentration factor are shown in Figure 2.4.1(3).

(5) Bending stress concentration factor α_B is to be calculated as follows:

$$\alpha_B = 0.625 f_1(r)\, f_2(w)\, f_3(e_k, w)\, f_4(b)\, f_5(d_H)$$

where: $f_1(r)$, $f_2(w)$, $f_3(e_k, w)$, $f_4(b)$, $f_5(d_H)$ may be obtained from Figures 3.3.3(1), (2), (3)a, b, c and (4), (5). Where the transition fillets of the crankpins or journals are filleted arc and the recess depth is T_H (as shown in Figure 2.4.1(3)), α_B value is to multiply $f_6(\delta)$ value obtained from Table 3.3.2 (6).

(6) Torsional stress concentration factor α_T is to be obtained from Figure 3.3.3 (6).

Coefficient *A* for two-stroke V-diesel engines **Table 3.3.2(1)**

Coefficient	Firing interval between two cylinders on one crankpin			
	36º	45º	60º	90º
A	0.70	0.66	0.615	0.585

Coefficient *A* for four-stroke V-diesel engines **Table 3.3.2(2)**

Coefficient	Minimum firing interval between two cylinders on one crankpin							
	45º	60º	75º	90º	270º	285º	300º	315º
A	0.665	0.630	0.610	0.599	0.594	0.596	0.597	0.598

Coefficient *C* for single acting in-line diesel engines **Table 3.3.2(3)**

two-stroke		two-stroke		four-stroke		four-stroke	
Number of cylinders	*C*	Number of cylinders	*C*	Number of cylinders	*C*	Number of cylinders	*C*
1	2.043	7	3.446	1	1.872	7	2.915
2	2.069	8	3.960	2	1.872	8	2.915
3	2.616	9	4.148	3	2.082	9	2.933
4	2.933	10	4.661	4	2.082	10	2.933
5	3.273	11	4.782	5	2.553	11	3.300
6	3.300	12	4.840	6	2.553	12	3.300

Coefficient *C* for two-stroke V-diesel engines **Table 3.3.2(4)**

Number of cylinders	Firing interval between two cylinders on one crankpin			
	36º	45º	60º	90º
2×3	3.768	3.464	3.546	3.675
2×4	4.138	3.800	4.400	5.630
2×6	5.469	5.684	6.563	5.286
2×8	6.504	7.010	6.469	7.003

Coefficient *C* for four-stroke V-diesel engines **Table 3.3.2(5)**

Number of cylinders	Minimum firing interval between two cylinders on one crankpin							
	45º	60º	75º	90º	270º	285º	300º	315º
2×3	2.934	2.833	2.648	2.511	3.307	3.309	3.380	3.309
2×4	3.224	3.103	3.056	3.159	3.105	3.183	3.150	2.848
2×6	3.859	3.613	3.404	3.471	3.864	4.146	4.155	4.187
2×8	4.274	4.035	4.500	4.455	4.706	4.314	3.648	3.480

The recess influence coefficient $f_6(\delta)$ of the transition fillets Table 3.3.2(6)

δ	0	0.15	0.25	0.35	0.45	0.55	0.60	0.65
$f_6(\delta)$	1	0.993	0.989	0.996	1.020	1.072	1.110	1.158

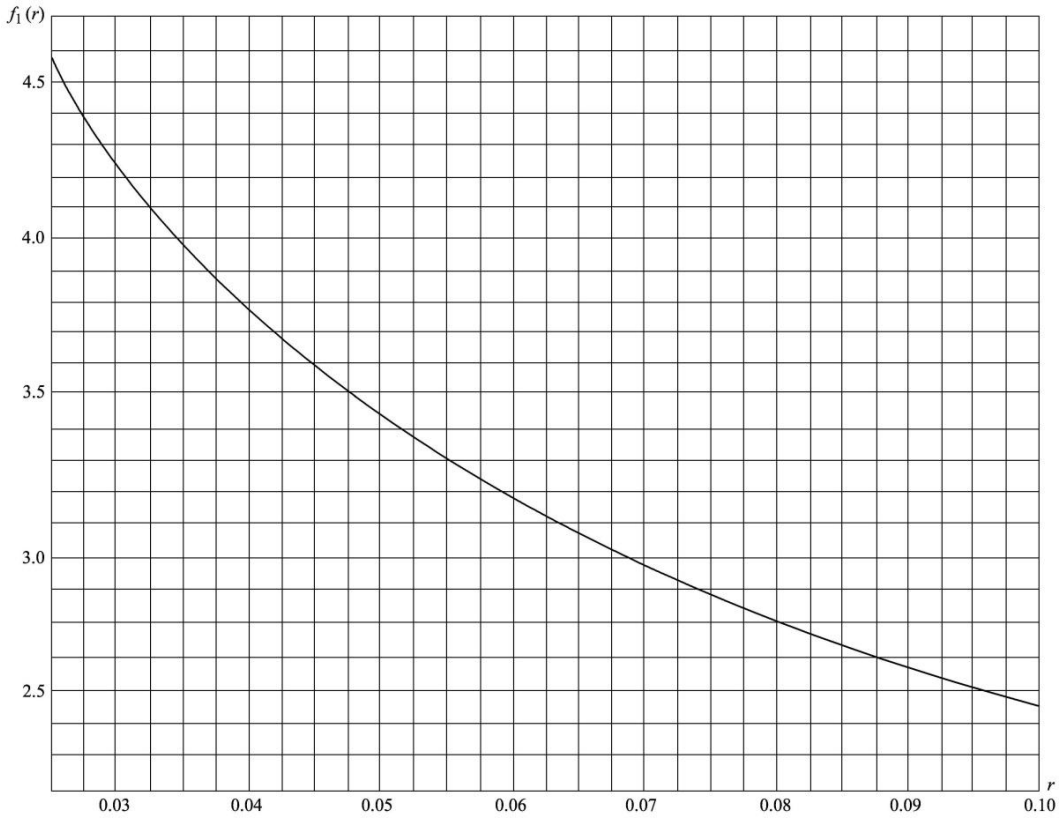


Figure 3.3.3(1)

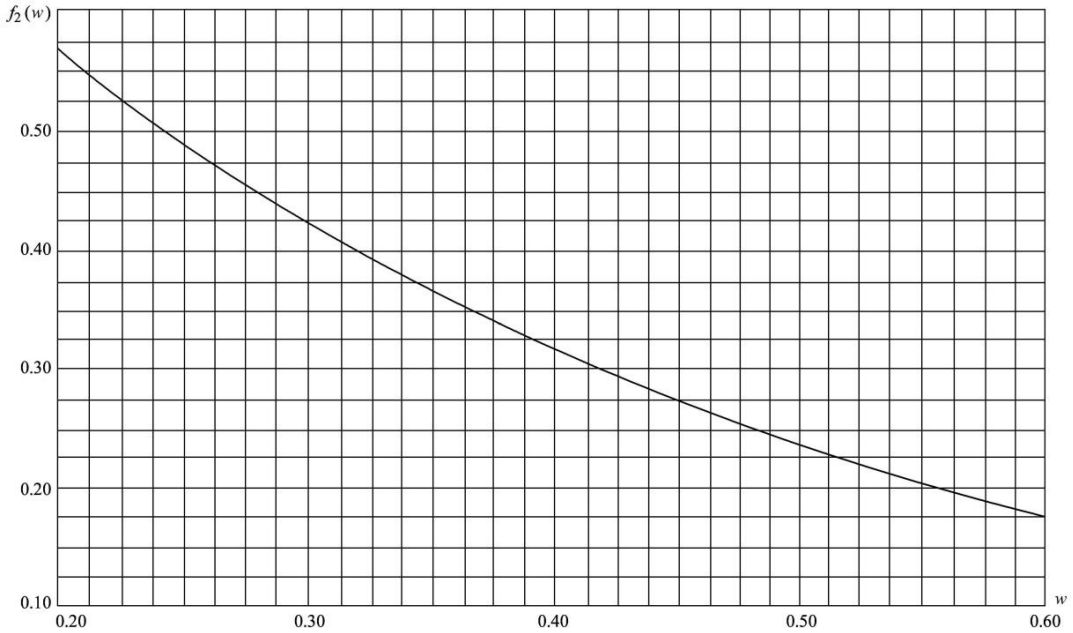


Figure 3.3.3(2)

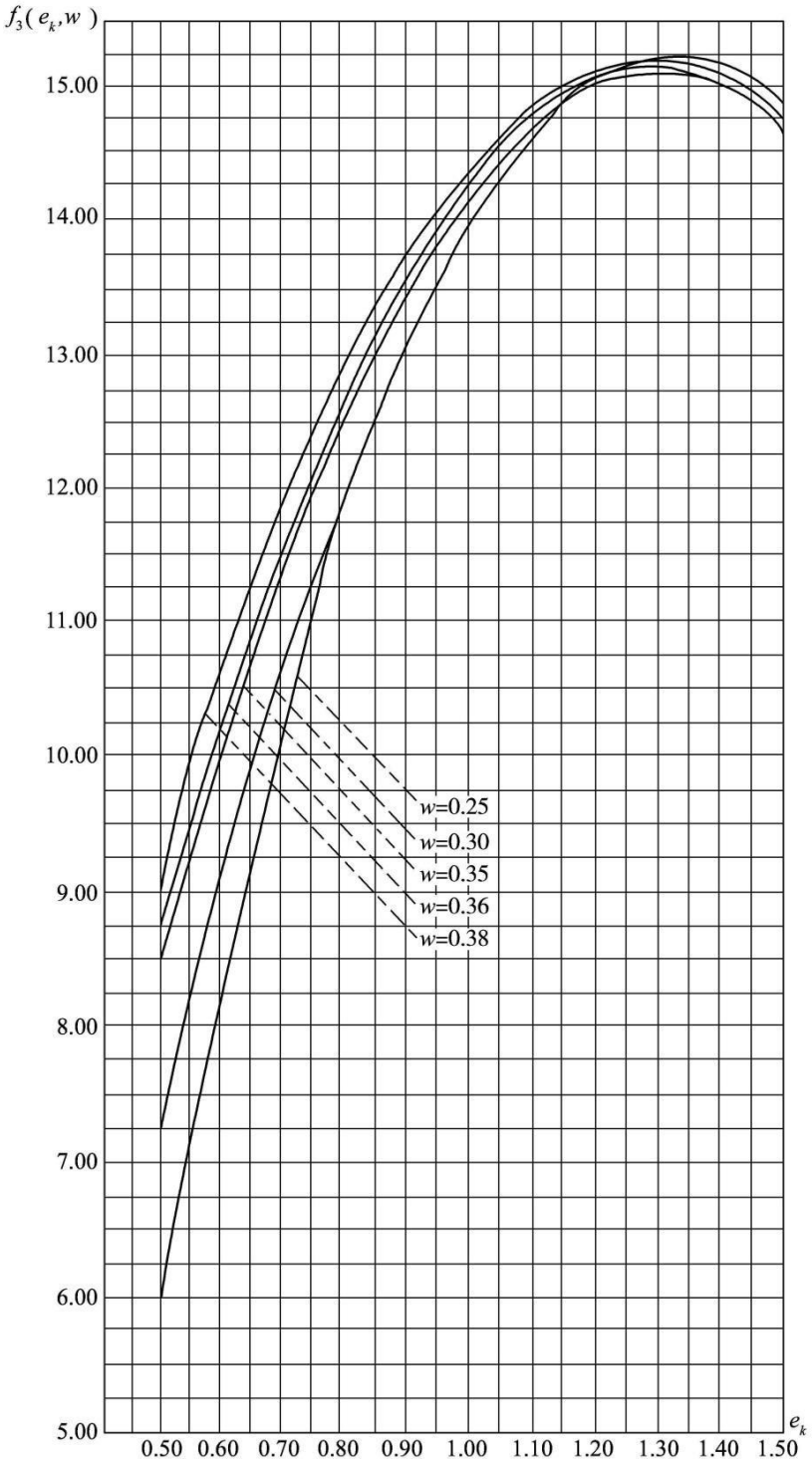


Figure 3.3.3(3)a

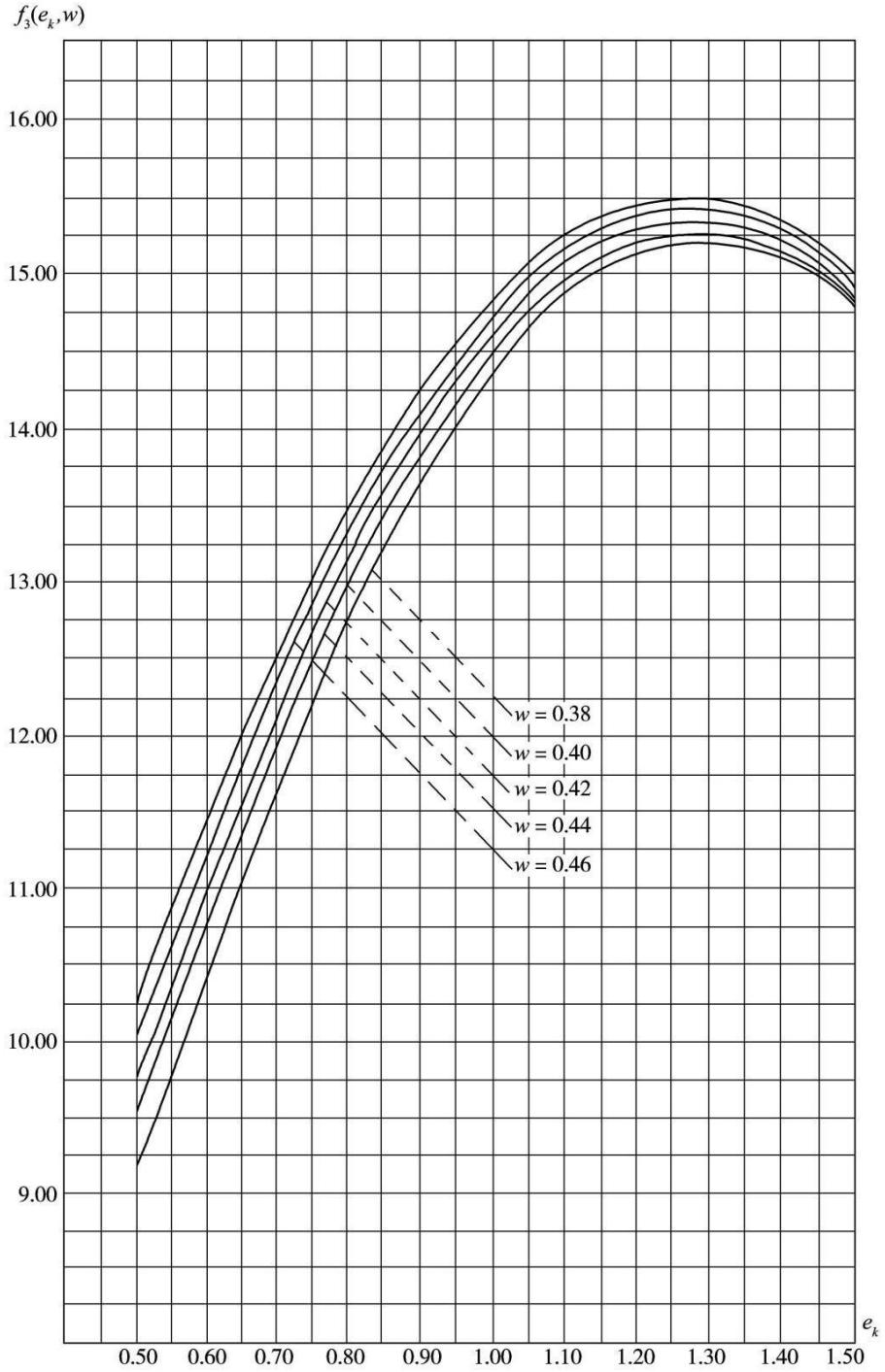


Figure 3.3.3(3)(b)

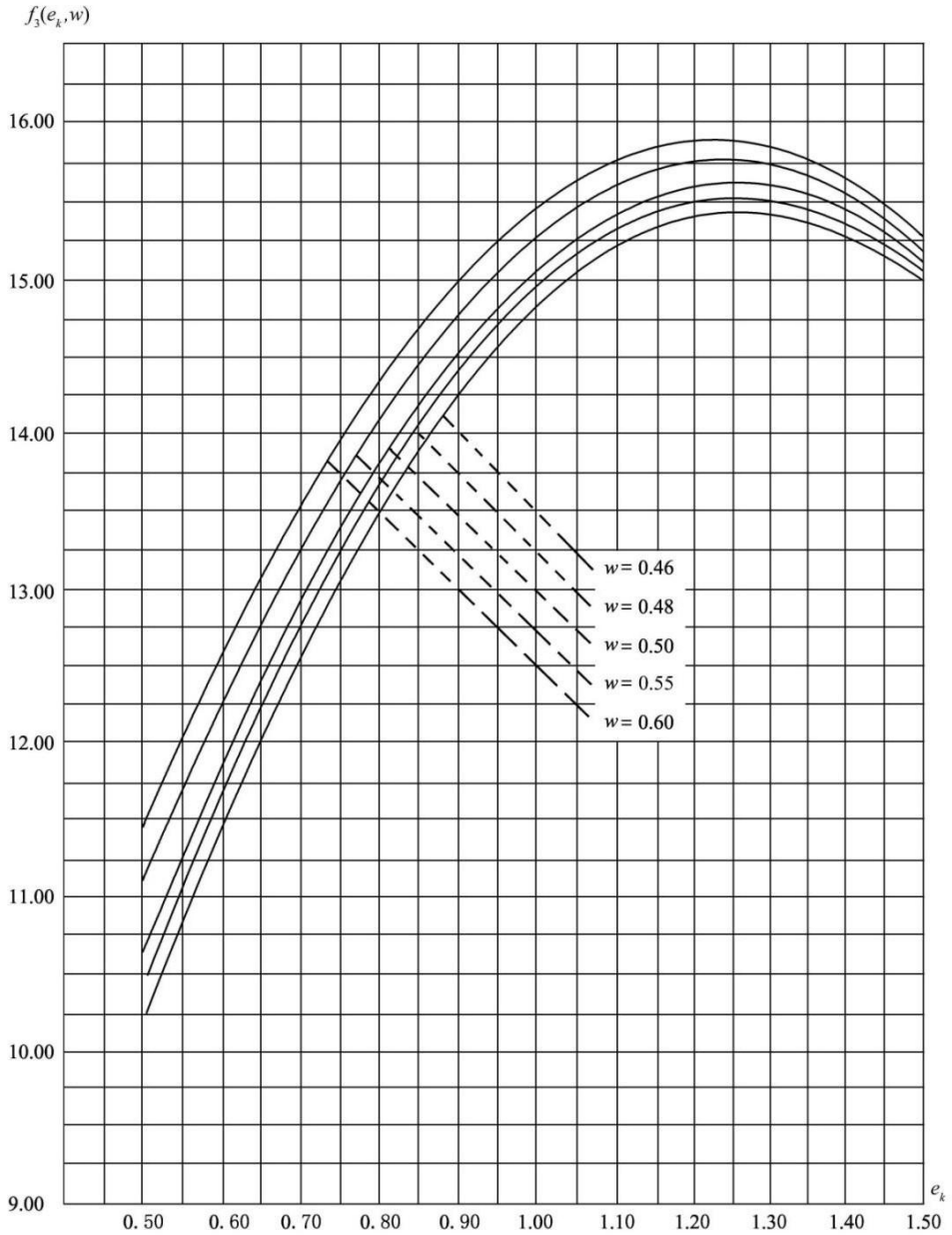


Figure 3.3.3(3)c

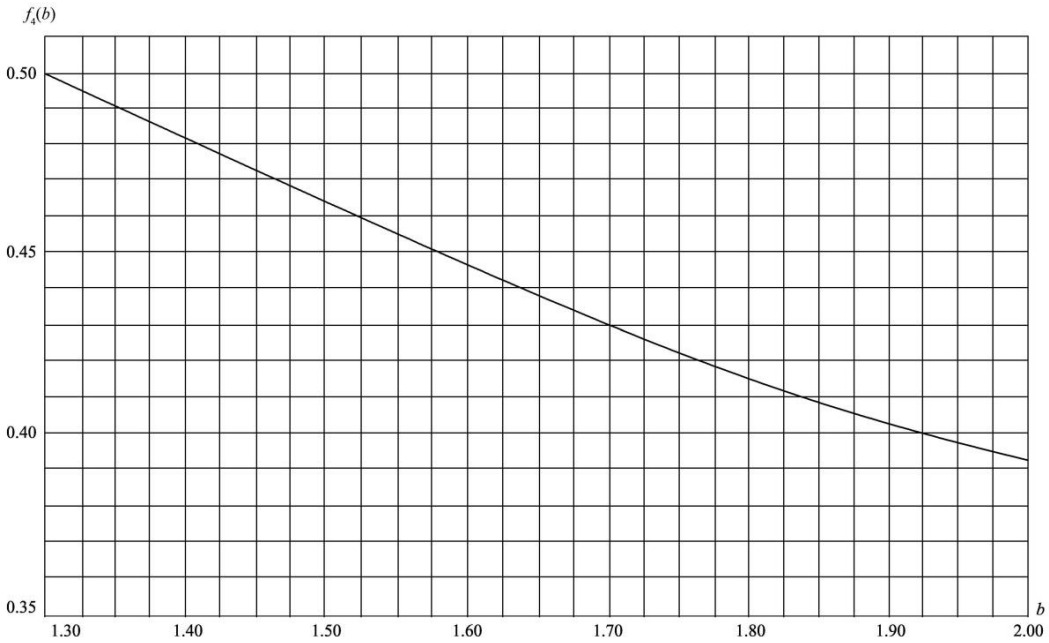


Figure 3.3.3(4)

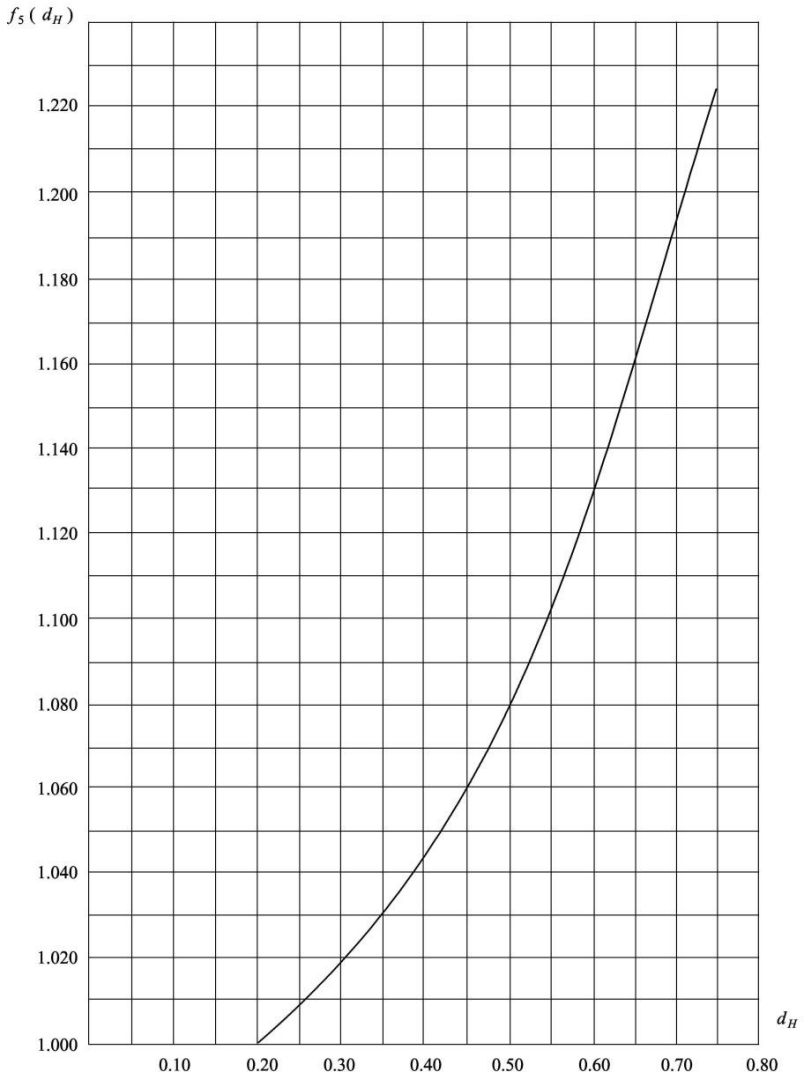


Figure 3.3.3(5)

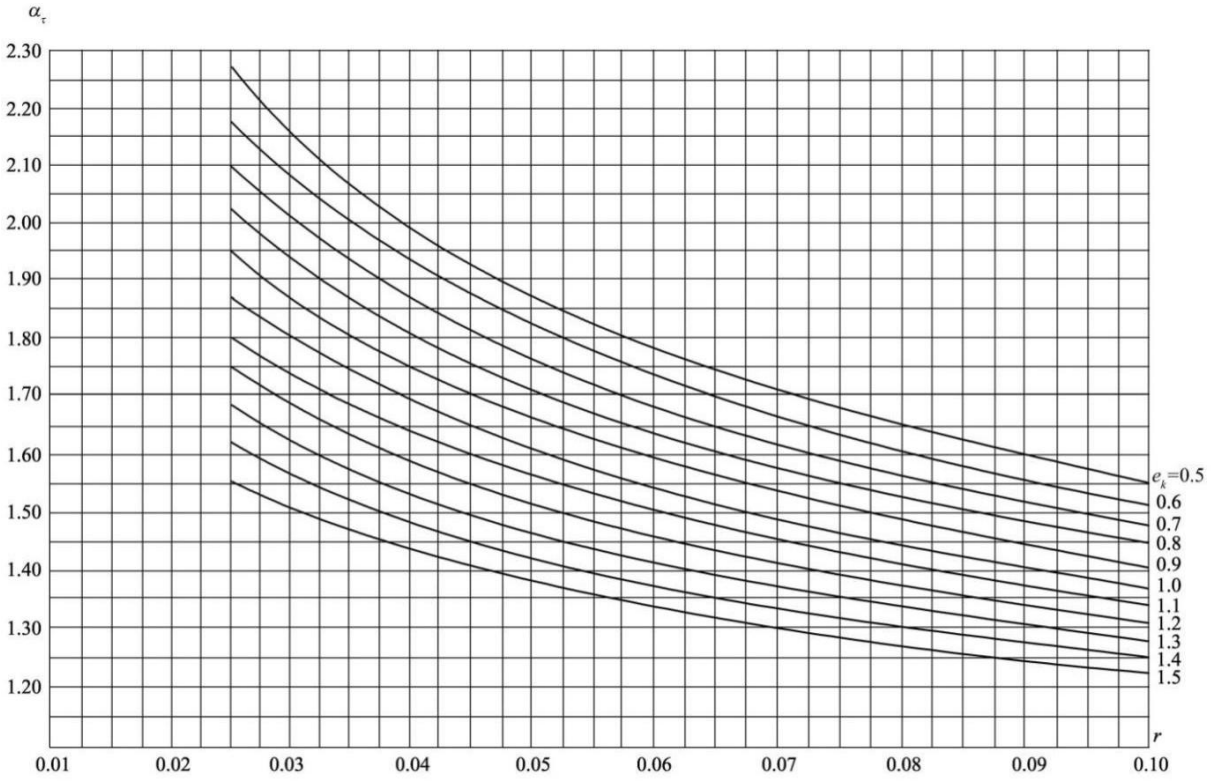


Figure 3.3.3(6)

4 Calculation of Shrink-fits of Semi-built Crankshafts

4.1 Geometry

4.1.1 All crank dimensions necessary for the calculation of shrink-fits are shown in Figure 4.1.1.

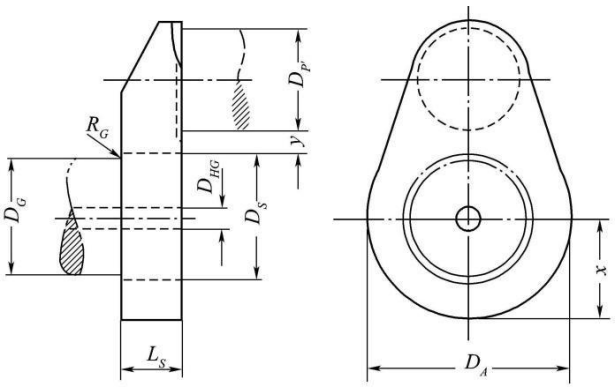


Figure 4.1.1 Crank Throw of Semi-built Crankshaft

where: D_S — shrink diameter, in mm;

L_S — length of shrink-fit, in mm;

D_A — outside diameter of web or twice the minimum distance x between centre-line of journals and outer edge of web, whichever is less, in mm;

y — distance between the adjacent generating lines of journal and pin.

$y \geq 0.05D_S$, in mm;

where y is less than $0.1D_S$, special consideration is to be given to the effect of the stress due to shrink on the fatigue strength at the crankpin fillet.

For other parameters, see 2.4.1 and Figure 2.4.1(3) of this Appendix.

4.1.2 For the arc radius of the journal transiting to the diameter of the shrink-fit, the following formulae are to be complied with:

$R_G \geq 0.015D_G$ and $R_G \geq 0.5(D_S - D_G)$, whichever is greater to be taken.

4.2 Maximum permissible hole diameter D_{BG} in the journal pin

4.2.1 In the case where the hole diameter in the journal pin is greater than the value obtained according to 4.2.2, then the calculation methods of minimum oversize Z_{min} and maximum oversize Z_{max} are not applicable to oversize of shrink-fit. In such case the maximum and minimum oversizes have to be established based on FEM calculations.

4.2.2 Calculation of maximum permissible hole diameter D_{BG}

The maximum permissible hole diameter D_{BG} in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 S_R M_{max}}{\mu \pi D_S^2 L_s R_{eH}}} \quad \text{mm}$$

where: S_R — safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments;

μ — coefficient for static friction, $\mu = 0.20$ for $L_S / D_S \geq 040$;

$M_{max} = M_T + 9.55 \frac{N_e}{n_e}$ N·m , where the maximum torque M_{max} corresponds to the maximum torque M_{Tmax} of mass points of the crankshaft determined in 2.3.3(1), i.e., after mean torque is considered, M_{max} may be obtained from nominal torque M_T (see 2.3.3(1)) and mean transfer torque of crankshaft;

R_{eH} — minimum yield strength of material for journal, in MPa;

N_e — rated power of diesel engines, in kW;

n_e — corresponding rated speed, in r/min.

4.3 Interference fit

4.3.1 Calculation of minimum oversize of shrink-fit

The minimum oversize of shrink-fit is to be determined by the greater value calculated in accordance with the formulae in 4.3.1(1) and 4.3.1(2).

(1) The minimum oversize of shrink-fit Z_{min} is to comply with the following formula:

$$Z_{min} \geq \frac{4 \times 10^3}{\pi \mu} \times \frac{S_R M_{max}}{E_m D_S L_S} \times \frac{1 - Q_A^2 Q_S^2}{(1 - Q_A^2)(1 - Q_S^2)} \quad \text{mm}$$

where: $Q_A = \frac{D_S}{D_A}$;

$Q_S = \frac{D_{BG}}{D_S}$;

E_m — Young's modulus, in MPa.

For other parameters, see 4.2.2 of this Appendix.

(2) Minimum oversize of shrink-fit Z_{min} is also to comply with the following formula:

$$Z_{min} \geq \frac{R_{eH} \cdot D_S}{E_m} \quad \text{mm}$$

where: R_{eH} — minimum yield strength of material for crank web, in MPa.

4.3.2 Determination of maximum permissible interference

The maximum interference of shrink-fit crankshaft is to limit the influence of the interference fit on mean stress in fillets. The maximum permissible interference Z_{max} may be calculated in accordance with the following:

$$Z_{max} \leq \frac{\delta_S D_S}{E_m} + \frac{0.8 D_S}{1000} \quad \text{mm}$$

5 Influence of Shafting on Crankshaft Strength

5.1 Summary

5.1.1 Crankshaft strength is not only related to crankshaft material, structure dimensions and technology, but also related to arrangement and installation of the whole shafting. During the stage of crankshaft design, fatigue strength of the crankshaft may be determined in accordance with the method in 2 of this Appendix, so that the allowable torsional stress, axial stress and compulsory repair span difference may be obtained.

5.1.2 During the stage of crankshaft design, the phenomena such as torsional vibration-axial vibration or torsion-longitudinal coupling vibration.

5.1.3 Where torsional antivibrator and/or axial antivibrator are installed, alternating torsional stress τ_H and additional axial bending stress σ_{ax} will be less than the values given in 2.3 and 2.5. Thus, the fatigue strength of the crankshaft may be increased.

5.1.4 Shafting arrangement and installation are to satisfy the requirements of torsional vibration, axial vibration and alignment as specified in rules and by the manufacturers. However, if one item is not in compliance with the specified value due to special condition, the actual value may be used in the fatigue acceptability factor Q. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft. However attention is to be paid not to exceed the fatigue strength of the material.

5.2 Torsional vibration

5.2.1 To simplify calculation, the allowable torsional vibration stress specified by ISC Rules may be treated as τ_H.

5.2.2 Where the allowable torsional vibration stress provided by the manufacturer exceeds that specified in the Rules, calculation is to be submitted for review in accordance with the requirements of 2.3.3.

5.2.3 During shafting calculation or actual measurement, if the allowable value of the rated speed is found to exceed that specified in the Rules or by the manufacturer, the actual τ_H may be used in the fatigue acceptability factor Q, and the actual value of the additional bending stress caused in axial vibration may be used. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft. However, the related calculation data are to be submitted for examination.

5.3 Longitudinal vibration

5.3.1 Propulsion shafting of two-stroke diesel engines is to be subject to longitudinal vibration calculation, while four-stroke diesel engines will not cause longitudinal vibration of shafting. It may be found from 2.5 of this Appendix that additional alternating bending stress σ_{ax} at fillet caused by axial vibration equals to 20 MPa, and additional alternating bending stress caused by shafting misalignment is 10 MPa. Therefore, the diesel engine manufacturers are to determine the allowable amplitude of longitudinal vibration of the crankshaft free end in accordance with 20 MPa additional axial stress.

5.3.2 Diesel engine manufacturers may also provide the allowable amplitude of longitudinal vibration in accordance with the determined crankshaft dimensions and technology parameters on the basis of $Q \geq 1.15$, and submit related calculations for examination.

5.3.3 Under special conditions, if the amplitude of the longitudinal vibration at rated speed during actual measurement is found to exceed the value specified in the Rules or by the manufacturers, the actual σ_{ax} and τ_H may be used in the acceptability factor Q. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft.

5.4 Alignment

5.4.1 After the diesel engine is connected with shafting, the bending moment and shearing force at the crankshaft ends due to shafting alignment causes additional bending stress upon crankpins. It is generally to be measured by means of controlling the difference of crank span.

5.4.2 For propulsion shafting of diesel engines needing to be aligned as specified in the Rules, reasonable alignment calculation and installation technology are to be submitted. Diesel engine manufacturers also specify the bending moment and shearing force in hot state and cold state on crankshaft of diesel engine.

During reasonable shafting alignment, if the bending moment and shearing force provided by the diesel engine manufacturers are not complied with but the crankshaft span difference still complies with the requirements, it is also acceptable. This is because the bending moment applied to the crankshaft end is shown in the form of the changing of the span difference.

5.5 Span difference

5.5.1 Additional bending stress σ_{add} given in 2.5 of this Appendix is actually the combination of additional stress σ_{ax} caused by axial vibration of shafting and additional compulsory repair bending stress σ_{aa}. Therefore, diesel engine manufacturers are to provide the span difference of the compulsory repair crankshafts in accordance with the σ_{aa} value adopted in the calculation of acceptability factor Q for actual use.

5.5.2 For two-stroke diesel engines, if there is no axial vibration of shafting or bending stress σ_{ax} caused by axial vibration < 20 MPa, or the margin of acceptability factor Q is greater, the compulsory repair span difference may be deduced on the basis of $Q \geq 1.15$. However, the related calculations are to be submitted for examination.

5.5.3 Where the span difference of the crankshafts of the ship in service exceeds the normal value or design value, the actual values τ_H, σ_{ax} and σ_{aa} may be used in Q. Where $Q \geq 1.15$ is complied with, it is safe to the crankshaft.

Annex I Guidance for Evaluation of Fatigue Tests of Crankshafts

Contents

1 Introduction
1.1 Small specimen testing
1.2 Full-size crank throw testing

2 Evaluation of test results
2.1 Principles
2.2 Staircase method
2.3 Modified staircase method
2.4 Calculation of sample mean and standard deviation
2.5 Confidence interval for mean fatigue limit
2.6 Confidence interval for standard deviation

3 Small specimen testing
3.1 Determination of bending fatigue strength
3.2 Determination of torsional fatigue strength
3.3 Other test positions
3.4 Correlation of test results

4 Full size testing
4.1 Hydraulic pulsation
4.2 Resonance tester
4.3 Use of results and crankshaft acceptability 5

Use of existing results for similar crankshafts

1 Introduction

Fatigue testing can be divided into two main groups: testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

1.1 *Small specimen testing*

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

1.2 *Full-size crank throw testing*

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4- point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to $R = -1$.

2 Evaluation of test results

2.1 Principles

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples are to be prepared so as to represent the “lower end” of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results are to be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in check of crankshaft fatigue strength, are to be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation is to be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in 2.4 of this Annex was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

2.2 *Staircase method*

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment is to be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

2.3 *Modified staircase method*

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment is to be selected to correspond to the expected level of the standard deviation.

This is continued with the same specimen until failure. Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens. The number of

run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens. The acquired result of a modified staircase method is to be used with care, since some results available indicate that testing a run-out on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced for high strength steels (e.g. UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

2.4 *Calculation of sample mean and standard deviation*

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

Number of samples, n=10

Furthermore, the method distinguishes between:

(1) *Less frequent event is failures C=1*

(2) *Less frequent event is run-outs C=2*

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test.

The sample mean can be calculated as follows:

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2} \right) \quad \text{when } C=1$$

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2} \right) \quad \text{when } C=2$$

The standard deviation can be found by:

$$s = 1.62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0.029 \right)$$

where:

S_{a0} is the lowest stress level for the less frequent occurrence;

d is the stress increment;

$$F = \sum f_i ;$$

$$A = \sum i \cdot f_i ;$$

$$B = \sum i^2 \cdot f_i ;$$

i is the stress level numbering;

f_i is the number of samples at stress level i;

The formula for the standard deviation is an approximation and can be used when:

(1) $\frac{B \cdot F - A^2}{F^2} > 0.3$;

(2) $0.5 \cdot s < d < 1.5 \cdot s$.

If any of these two conditions are not fulfilled, a new staircase test is to be considered or the standard deviation is to be taken quite large in order to be on the safe side.

If increment d is greatly higher than the standard deviation s, the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small.

Respectively, if increment d is much less than the standard deviation s, the procedure leads to a higher standard deviation and a slightly lower sample mean.

2.5 *Confidence interval for mean fatigue limit*

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.
The confidence interval for the sample mean value with unknown variance is known to be distributed according to the *t*-distribution (also called *student's t-distribution*) which is a distribution symmetric around the average.
The confidence level normally used for the sample mean is 90%, meaning that 90% of sample means from repeated tests will be above the value calculated with the chosen confidence level. Figure I-2.1 shows the *t*-value for (1 - α)·100% confidence interval for the sample mean.

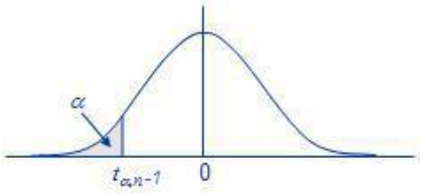


Figure I-2.1 Student's t-distribution

If S_a is the empirical mean and *s* is the empirical standard deviation over a series of *n* samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the (1 - α)·100% confidence interval for the mean is:

$$P\left(S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1 - \alpha$$

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

2.6 *Confidence interval for standard deviation*

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with *n* - 1 degrees of freedom.
The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. Figure I-2.2 shows the chi-square for (1 - α)·100% confidence interval for the variance.

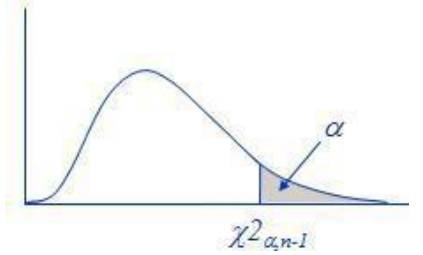


Figure I-2.2 Chi-square distribution

An assumed fatigue test value from *n* samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2. Then a (1 - α)·100% confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < x^2_{\alpha,n-1}\right) = 1 - \alpha$$

A (1 - α)·100% confidence interval for the standard deviation is obtained as follows:

$$S_{x\%} = \sqrt{\frac{n-1}{x^2_{\alpha,n-1}}} \cdot s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

3 Small specimen testing

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens are to be representative for the fillet fatigue strength, they are to be taken out close to the fillets, as shown in Figure I-3.1.

It is to be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilizing the finite element method.

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

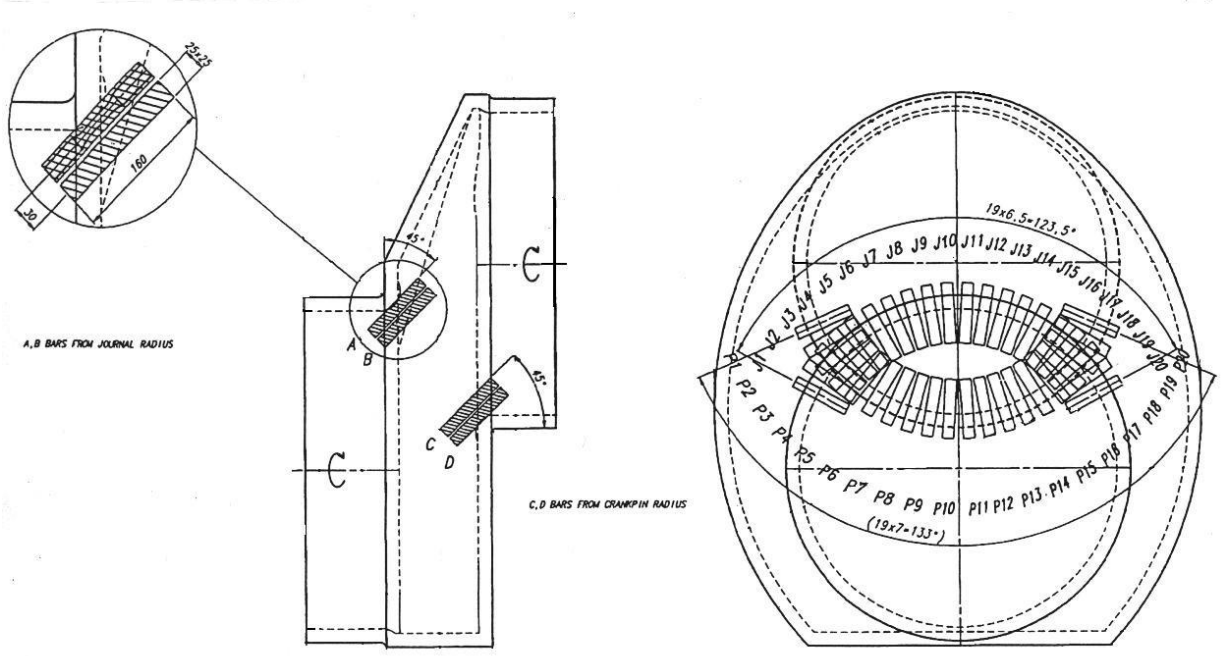


Figure I-3.1 Specimen locations in a crank throw

3.1 Determination of bending fatigue strength

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio $R = -1$) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen is to be taken in 45 degrees angle as shown in Figure I-3.1.

(1) If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Figure I-3.1.

(2) If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens are to be restricted to the vicinity of the crank plane.

3.2 *Determination of torsional fatigue strength*

(1) If the specimens are subjected to torsional testing, the selection of samples is to follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.

(2) If the specimens are tested in push-pull and no further information is available, the samples are to be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the full-size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to re-sample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

3.3 *Other test positions*

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

3.4 *Correlation of test results*

The fatigue strength achieved by specimen testing is to be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).
When using the bending fatigue properties from tests mentioned in this section, it is to be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.
In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognized when using the von Mises or a multi-axial criterion such as Findley.
If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one is to consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.
Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a *K*-factor for cgf. Direct testing of samples from a clean and cgf forged crank is preferred.

4 Full size testing

4.1 Hydraulic pulsation

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any *R*-ratio.
Although the applied load is to be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.
Furthermore, it is important that the test rig provides boundary conditions as defined in 2.4.5(3)①~③ of this Appendix.
The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

4.2 *Resonance tester*

A rig for bending fatigue normally works with an *R*-ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. Figure I-4.1 shows a layout of the testing arrangement.
The applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

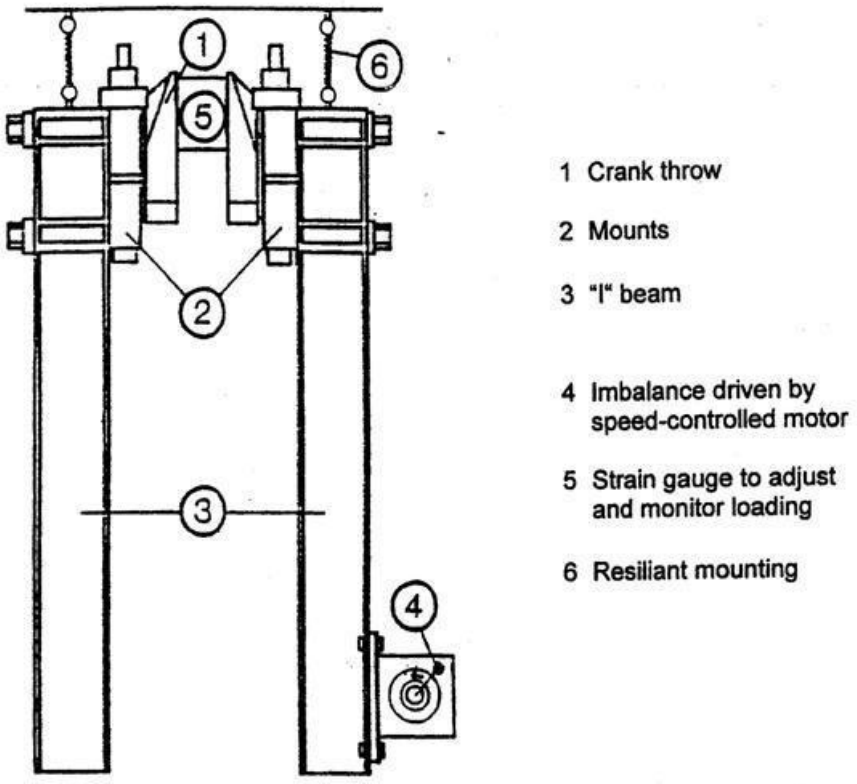
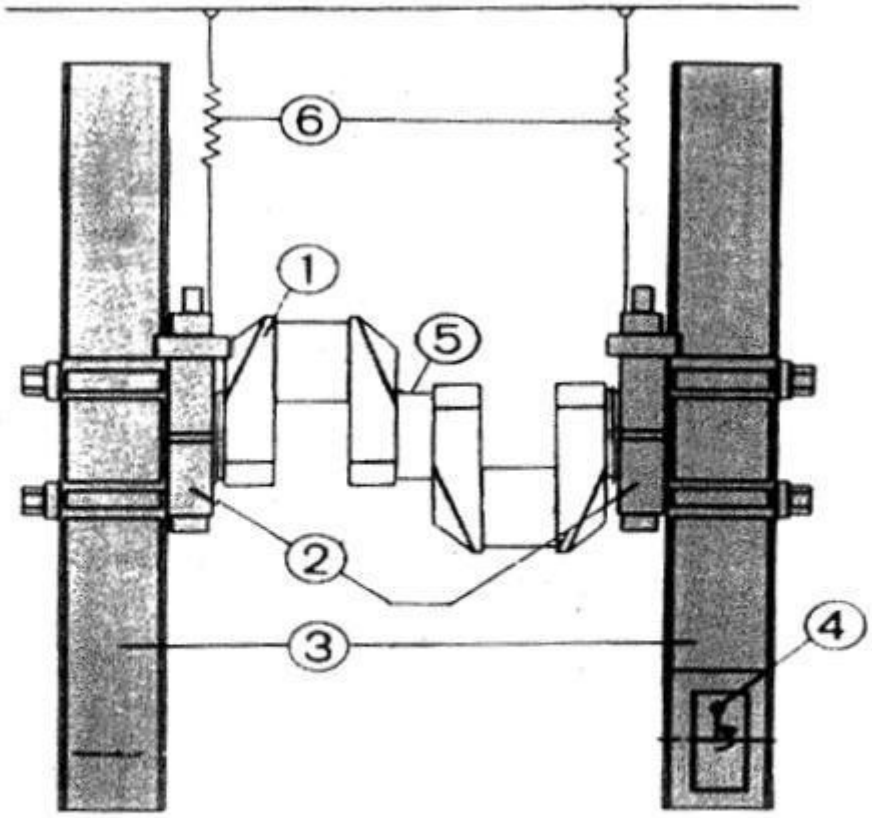


Figure I-4.1 An example of testing arrangement of the resonance tester for bending loading

Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.
In an engine, the crankpin fillets normally operate with an *R*-ratio slightly above -1 and the journal fillets slightly below -1. If found necessary, it is possible to introduce a mean load (deviate from $R = -1$) by means of a spring preload.
A rig for torsion fatigue can also be arranged as shown in Figure I-4.2. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.
This sideway movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.



① crankthrow
② clamping jaw
③ I-profiled beams
④ motor-driven eccentric weight
⑤ strain gage
⑥ elastic suspension

Figure I-4.2 An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

Since sideway movements can cause some bending stresses, the plain portions of the crankpins are also to be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.
Similarly, to the bending case the applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

4.3 *Use of results and crankshaft acceptability*

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, see 2.8 of this Appendix, the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

where:

σ_{DWCT}— fatigue strength by bending testing;

τ_{DWCT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}$$

where:

σ_{DWOT}—fatigue strength by means of largest principal stress from torsion testing;

$$\sigma_v = \pm \frac{1}{3} \sigma_{BO} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\sigma_{TO}}{\sigma_{BO}} \right)^2} \right], \quad \text{MPa}$$

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

where:

σ_{DWJT}— fatigue strength by bending testing;

τ_{DWJT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

5 *Use of existing results for similar crankshafts*

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

(1) *Material:*

- Similar material type;
- Cleanliness on the same or better level;
- The same mechanical properties can be granted (size versus hardenability).

(2) *Geometry:*

- Difference in the size effect of stress gradient is insignificant or it is considered;
- Principal stress direction is equivalent. See Part 3 of this Annex.

(3) *Manufacturing:*

- Similar manufacturing process.

Induction hardened or gas nitrited crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately ± 30 % of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

It has to be noted also what some recent research has shown: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point.
In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7. Based on a publication by Yukitaka Murakami "Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions" the reduction is suggested to be 5 % per decade especially when the hydrogen content is considered to be high.

Annex II Guidance for Calculation of Fatigue Strength of Surface Treated Fillets and Oil Bore Outlets

Contents

1 Introduction

2 Definition of surface treatment
2.1 Surface treatment methods

3 Calculation principles
3.1 Evaluation of local fillet stresses
3.2 Evaluation of oil bore stresses
3.3 Acceptability criteria

4 Induction hardening
4.1 Local fatigue strength

5 Nitriding
5.1 Local fatigue strength

6 Cold forming
6.1 Stroke peening by means of a ball
6.1.1 Use of existing results for similar crankshafts
6.2 Cold rolling
6.2.1 Use of existing results for similar crankshafts

1 *Introduction*

This Annex deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Please note that measurements or more specific knowledge are to be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values are to be chosen from the end of the range that would be on the safe side for calculation purposes.

2 *Definition of surface treatment*

Surface treatment is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties - such as hardness, chemistry or residual stresses – from the surface to the core.

2.1 Surface treatment methods

Table 2.1 covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Surface treatment methods and the characteristics they affect *Table 2.1*

Treatment method	**Affecting**
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness and residual stresses
Case hardening	Chemistry, hardness and residual stresses
Die quenching (no temper)	hardness and residual stresses
Cold rolling	residual stresses
Stroke peening	residual stresses
Shot peening	residual stresses
Laser peening	residual stresses
Ball coining	residual stresses

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this Annex. In addition, die quenching can be considered in the same way as induction hardening.

3 *Calculation principles*

The basic principle is that the alternating working stresses are to be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also section 6.1 of this Annex for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment- i.e. to cover the depth all the way to the core.

Consideration of the local fatigue strength is to include the influence of the local hardness, residual stress and mean working stress. The influence of the “giga-cycle effect”, especially for initiation of subsurface cracks, is to be covered by the choice of safety margin.

It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses. This forms a “weak spot” and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. Figure II-3.1 indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour. The acceptability criterion is to be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

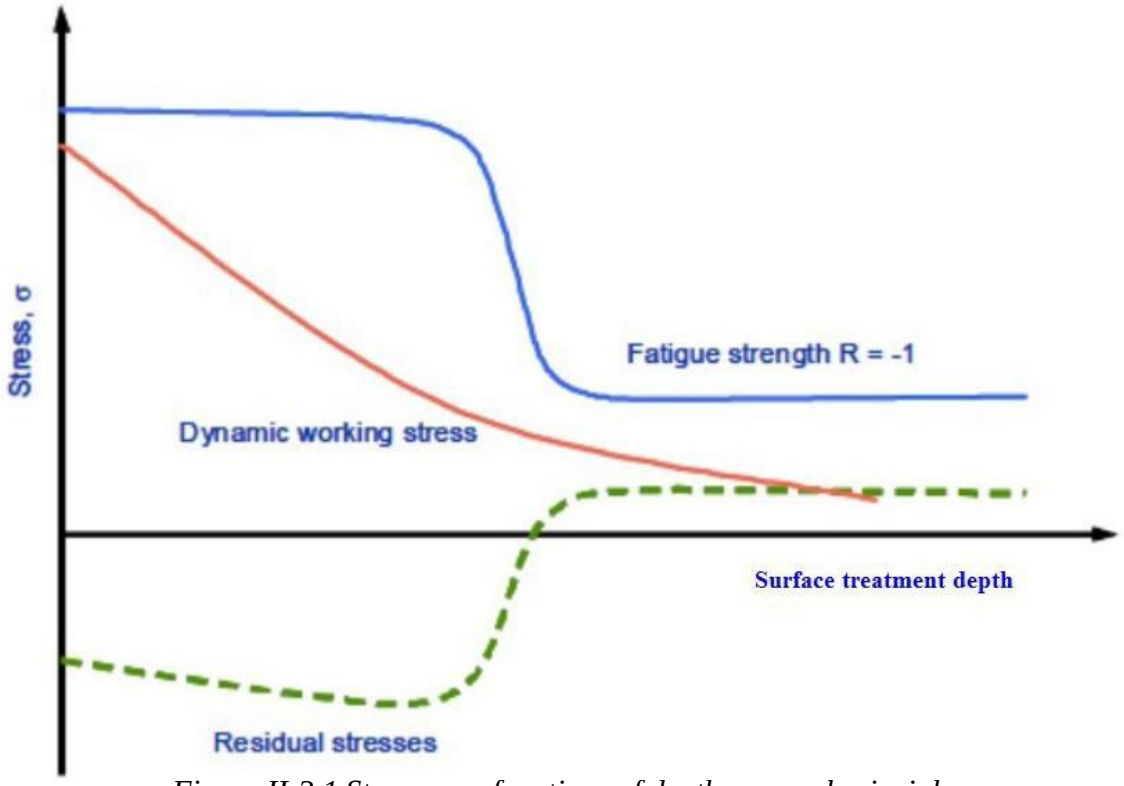


Figure II-3.1 Stresses as functions of depth, general principles

3.1 Evaluation of local fillet stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in 2.4.5 of this Appendix. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in 2.4 of this Appendix if within its validity range, and a relative stress gradient inversely proportional to the fillet radius.

Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B\text{-}local}$ and $\alpha_{T\text{-}local}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B\text{-}local}$ and $\alpha_{T\text{-}local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G. The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs for crankpin fillet are then functions of depth *t* according to Equation 3.1 as shown in Figure II-3.2 for bending and respectively for torsion in Equation 3.2 and Figure II-3.3. The corresponding bending SCF and torsion SCF for the journal fillet can be found by replacing R_H with R_G and D_P with D_G.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e_1^{\frac{-2t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + e^2}} \right)^{\frac{0.6}{\sqrt{\alpha_B}}} \qquad (3.1)$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e_1^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D_p} \right)^{\frac{1}{\sqrt{\alpha_T}}} \qquad (3.2)$$

where: e_1 is natural constant, and other symbols are defined in 2.4.1 in this Appendix.

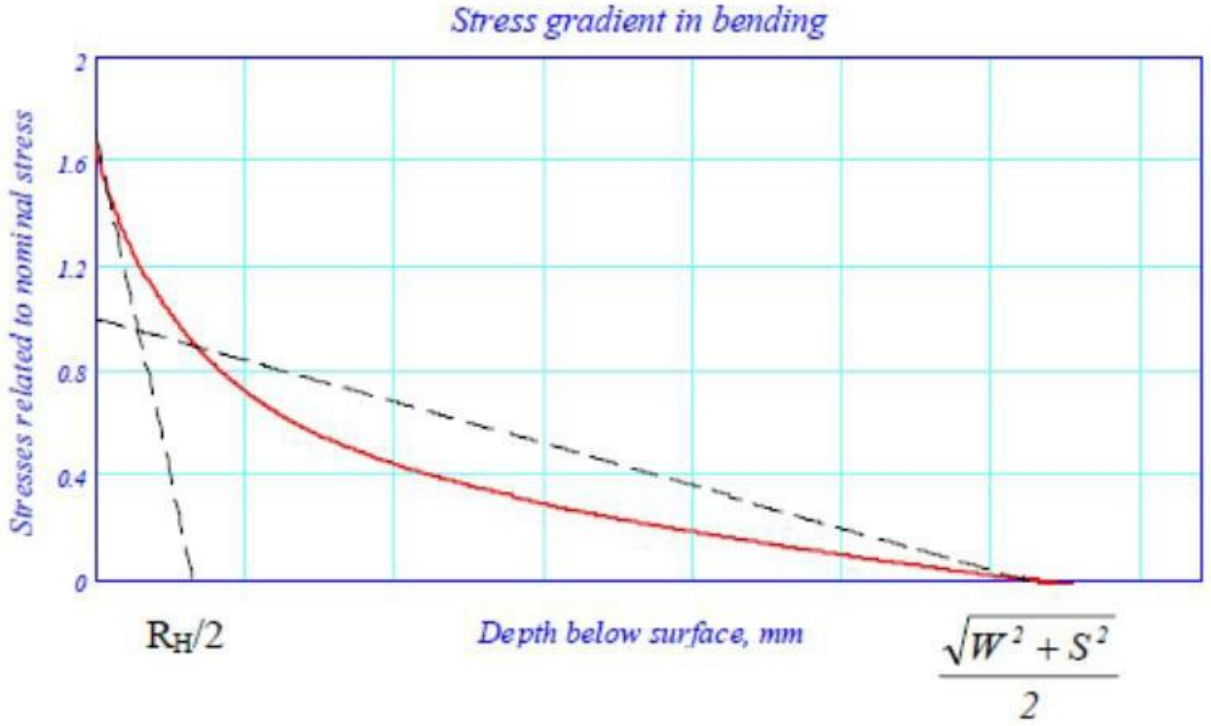


Figure II-3.2 Bending SCF in the crankpin fillet as a function of depth

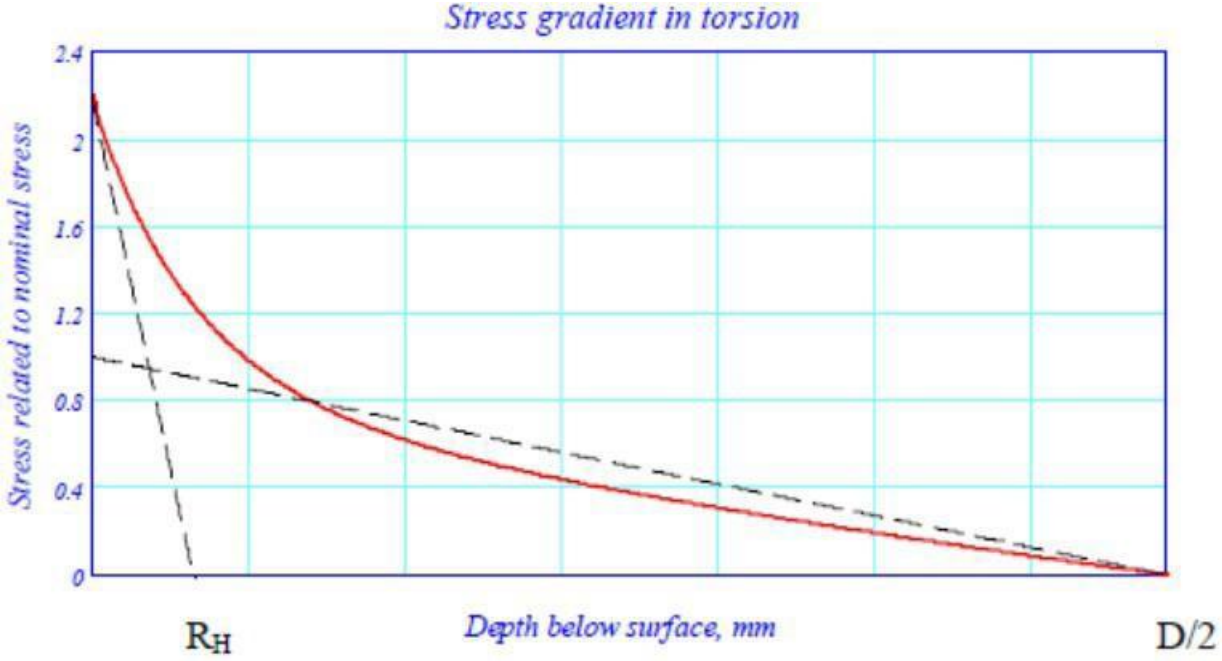


Figure II-3.3 Torsional SCF in the crankpin fillet as a function of depth

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA is to be used to determine the actual stresses in the transition zone.

3.2 Evaluation of oil bore stresses

Stresses in the oil bores can be determined also by FEA. The element size is to be less than 1/8 of the oil bore diameter D_o and the element mesh quality criteria is to be followed as prescribed in Annex III. The fine element mesh is to continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque – see Annex III item 3.1 – and the bending moment, with four-point bending as in Annex III item 3.2 of this Appendix.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from 2.4 of this Appendix if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in 2.6 of this Appendix.

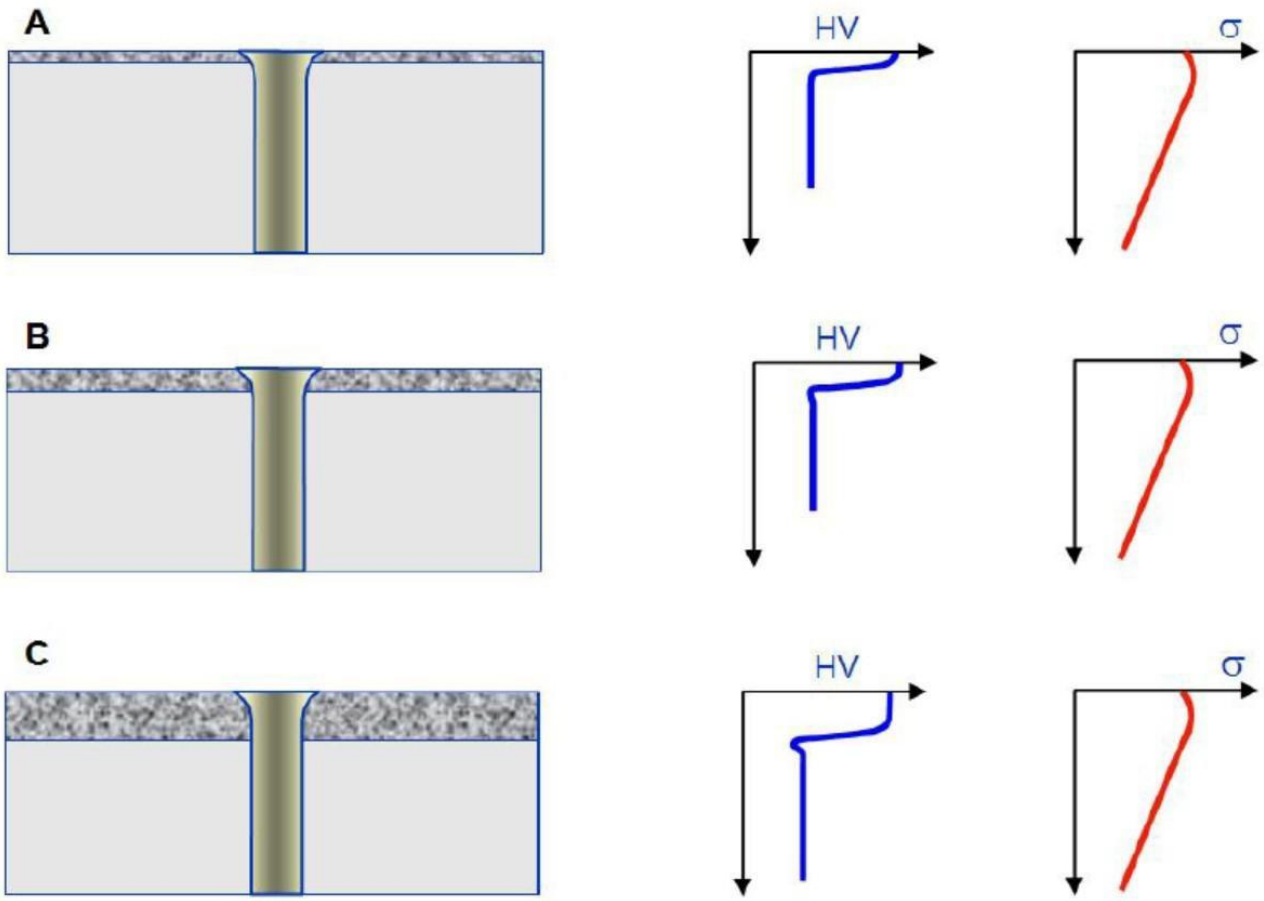


Figure II-3.4 Stresses and hardness in induction hardened oil holes

Figure II-3.4 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.
The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Figure II-3.4, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion (1-2*tH/D*) of the peak stresses where *tH* is the hardening depth.
The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B-local}$ and $\gamma_{T-local}$ have different shapes, because of the different stress gradients.
The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B-local}$ and $\gamma_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth *t*:

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_o}} + 1 \qquad (3.3)$$

$$\gamma_{T-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_o}} + 1 \qquad (3.4)$$

where: e_1 is natural constant, and other symbols are defined in 2.4.1 in this Appendix.

3.3 Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations; the equivalent alternating stress and the fatigue strength ratio are compared to an acceptability factor of $Q \geq 1.15$ for oil bore outlets, crankpin fillets and journal fillets. This is to be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

4 *Induction hardening*

Generally, the hardness specification is to specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be HV0.5-HV5.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

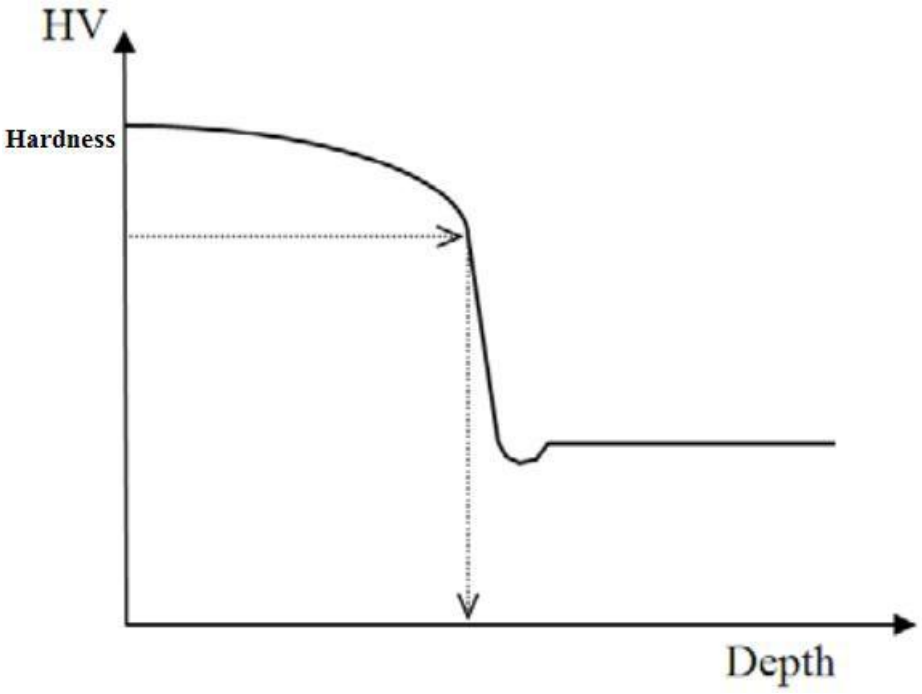


Figure II-4.1 Typical hardness as a function of depth

The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

In the case of crankpin or journal hardening only, the minimum distance to the fillet is to be specified due to the tensile stress at the heat-affected zone as shown in Figure II-4.2.

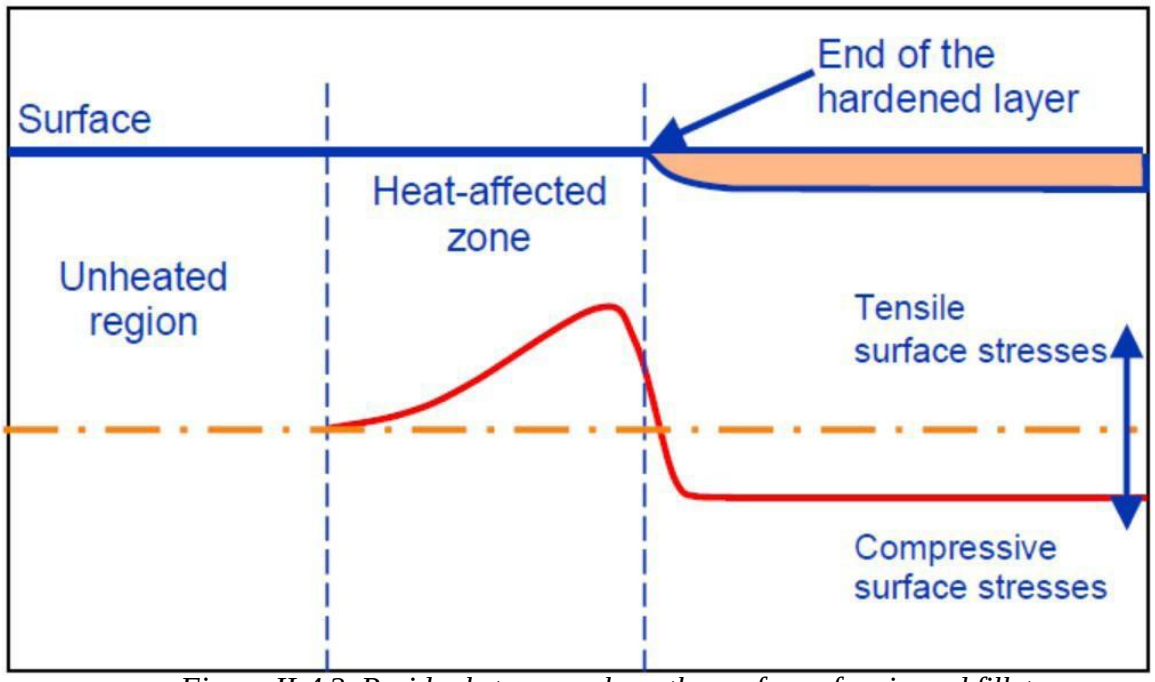


Figure II-4.2 Residual stresses along the surface of a pin and fillet

If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:
(1) The hardness profile consists of two layers (see Figure II-4.1):
- Constant hardness from the surface to the transition zone;
- Constant hardness from the transition zone to the core material;

(2) Residual stresses in the hard zone of 200 MPa (compression);
(3) Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided;
(4) Transition-zone maximum residual stresses (von Mises) of 300 MPa tension.
If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

4.1 Local fatigue strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Annex I of this Appendix. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends.
Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.
Alternatively, the surface fatigue strength can be determined empirically as follows where *HV* is the surface Vickers hardness. The Equation 4.1 provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of R = -1:
It has to be noted also that the mean stress influence of induction-hardened steels may be significantly

$$\sigma_{Fsurface} = 400 + 0.5 \cdot (HV - 400) \quad \text{MPa} \quad (4.1)$$

higher than that for QT steels.
The fatigue strength in the transition zone, without taking into account any possible local hardness drop, is to be determined by the equation introduced in 2.7 of this Appendix.
For journal and respectively to crankpin fillet applies:

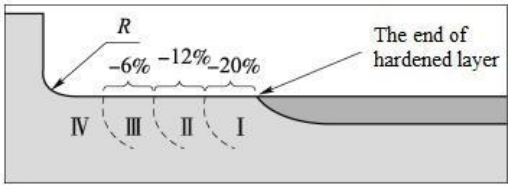
$$\sigma_{\text{Ftransition,cpin}} = \pm K \cdot \left(0.42 R_m + 39.3\right) \cdot \left[0.264 + 1.073 \text{Y}^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m} \cdot \sqrt{\frac{1}{\text{X}}}\right] \quad (4.2)$$

where:

$Y = D_G$ and $X = R_G$ for journal fillet
$Y = D_p$ and $X = R_H$ for crankpin fillet
$Y = D_p$ and $X = D_o/2$ for oil bore outlet
The influence of the residual stress is not included in 4.2.
For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.
When the residual stresses are known to be lower, also smaller value of subtraction is to be used. For low-strength steels the percentage chosen is to be higher.
For the purpose of considering surface fatigue near the end of the hardened zone – i.e. in the heat-affected zone shown in the Figure II-4.2 - the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Table 4.1, from the value determined by the above formula.

The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet

Table 4.1

Zone	Scope	Strength coefficient	Illustration of heat affected zones and strength coefficients
I II III IV	0-tH tH-2tH 2tH-3tH 3tH or more	0.8 0.88 0.94 1	

5 Nitriding

The hardness specification is to include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be HV0.5.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth tN as the depth to a hardness of 50 HV above the core hardness.

The hardening profile is to be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}} \right)^{\left(\frac{t}{tN}\right)^2} \qquad (5.1)$$

where:

t = The local depth;

$HV(t)$ = Hardness at depth t;

HV_{core} = Core hardness (minimum);

$HV_{surface}$ = Surface hardness (minimum);

tN = Nitriding depth as defined above (minimum).

5.1 Local fatigue strength

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Annex I of this Appendix.

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{Fsurface} = 450 \text{ MPa} \qquad (5.2)$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of R = -1.

The fatigue strength in the transition zone can be determined by the equation introduced in 2.7 of this Appendix. For crankpin and respectively to journal applies:

$$\sigma_{Ftransition,cpin} = \pm K \cdot (0.42 R_m + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m} \cdot \sqrt{\frac{1}{X}} \right] \qquad (5.3)$$

where:

$Y = D_G$ and $X = R_G$ for journal fillet;

$Y = D_p$ and $X = R_H$ for crankpin fillet;

$Y = D_p$ and $X = D_0/2$ for oil bore outlet.

Note that this fatigue strength is not assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrited components have no such distinct transition to the core, as indicated by Figure II-5.1. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation is to be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition

point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material are to be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting t=1.2tN.

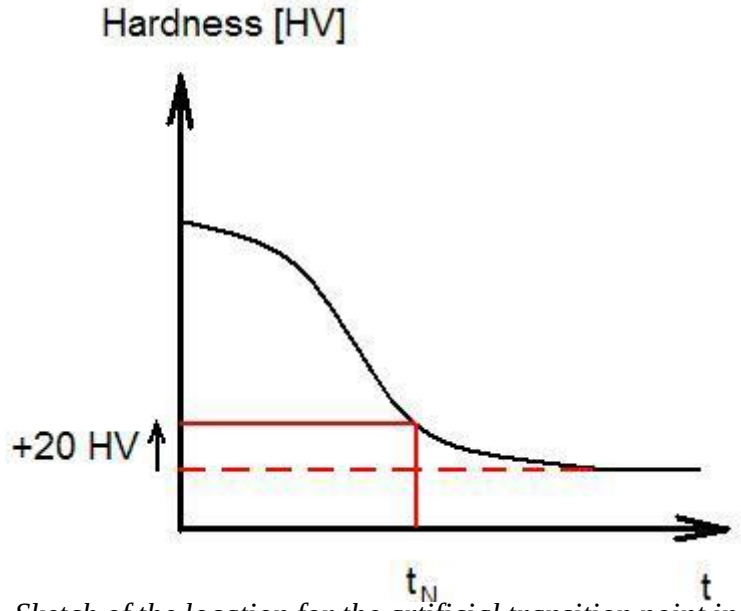


Figure II-5.1 Sketch of the location for the artificial transition point in the depth direction

6 Cold forming

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Annex I of this Appendix. Such testing is normally carried out as four-point bending, with a working stress ratio of R = -1. From these results, the bending fatigue strength - surface- or subsurface-initiated depending on the manner of failure-can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio $\sqrt{3}$ (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

6.1 Stroke peening by means of a ball

The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $\sqrt{3}$, the von Mises criterion is to be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength is to be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength is not to be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. This is illustrated in Figure II-6.1. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual

stresses below the surface “arrest” small surface cracks.

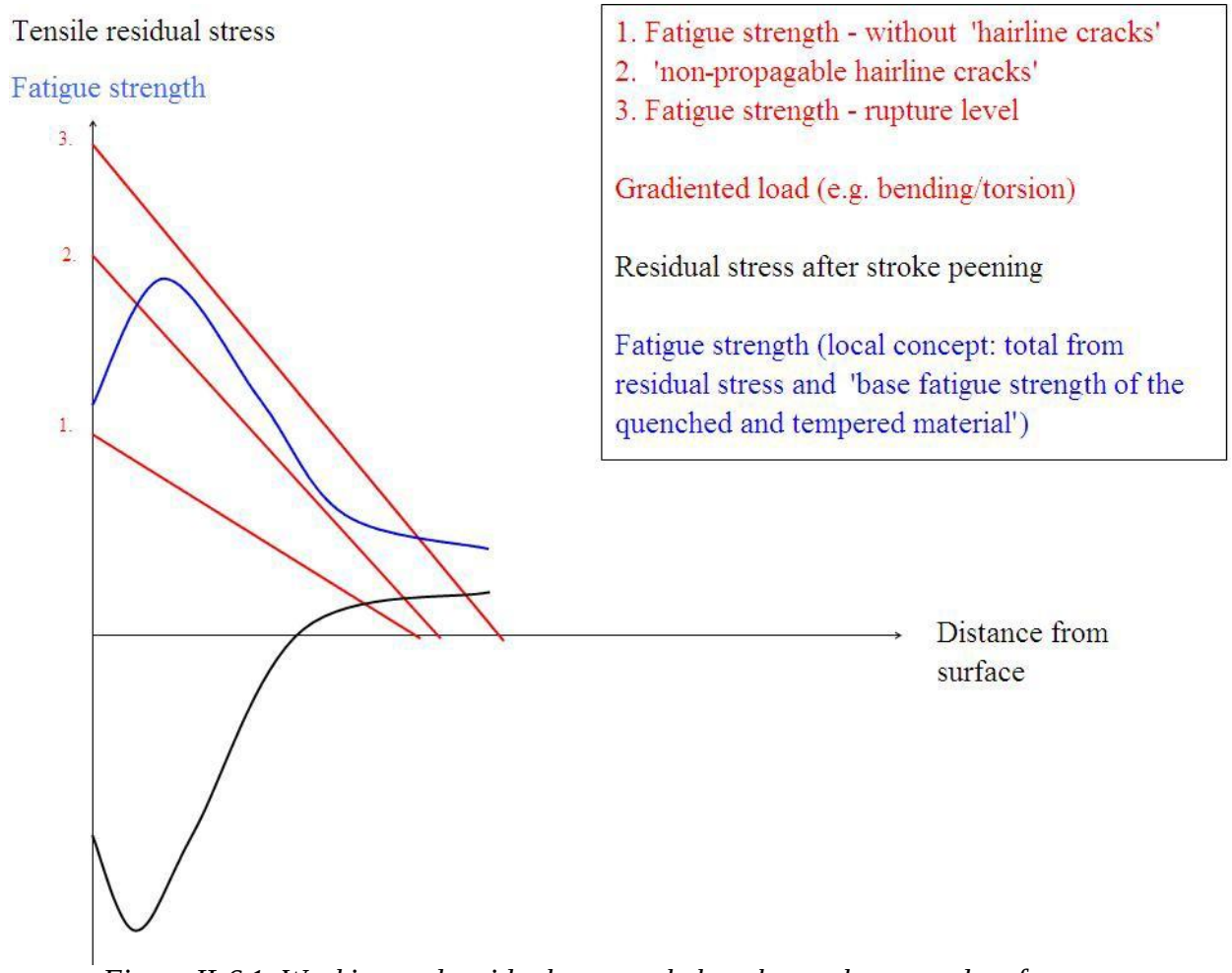


Figure II-6.1 Working and residual stresses below the stroke-peened surface

In fatigue testing with full-size crankshafts these small “hairline cracks” are not to be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, is to be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts’ fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets are to be determined by a full-size crankshaft test.

6.1.1 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

(1) Ball size relative to fillet radius within ±10% in comparison to the tested crankshaft;

(2) At least the same circumferential extension of the stroke peening;

(3) Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation;

(4) Similar base material, e.g. alloyed quenched and tempered;

(5) Forward feed of ball of the same proportion of the radius;

(6) Force applied to ball proportional to base material hardness (if different);

(7) Force applied to ball proportional to square of ball radius.

6.2 Cold rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are

applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio $\sqrt{3}$, the von Mises criterion is to be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength is to be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-rolled material, the torsional fatigue strength is not to be assumed to be more than 2/3 of x% above that of the non-rolled material.

6.2.1 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

(1) At least the same circumferential extension of cold rolling;

(2) Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation;

(3) Similar base material, e.g. alloyed quenched and tempered;

(4) Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment.

Annex III Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of crankshafts through utilisation of the Finite Element Method

Contents

1 General

2 Model requirements
2.1 Element mesh recommendations
2.2 Material
2.3 Element mesh quality criteria

3 Load cases and assessment of stress
3.1 Torsion
3.2 Bending

1 *General*

The objective of the analysis described in this Annex is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method specified in 2.4.4 of this Appendix is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in this Appendix, principal stresses are to be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

2 *Model requirements*

The basic recommendations and assumptions for building of the FE-model are presented in 2.1 of this Annex. The final FE-model must meet one of the criteria in 2.3 of this Annex.

2.1 Element mesh recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

(1) The model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.

(2) The following element types are used in the vicinity of the outlets: 10-node tetrahedral elements; 8-node hexahedral elements; 20-node hexahedral elements.

(3) The following mesh properties for the oil bore outlet are used:

- Maximum element size a = r / 4 through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion).
- Recommended manner for element size in the fillet depth direction: first layer's thickness equal to element size of *a*; second layer's thickness equal to element size of *2a*; third-layer's thickness equal to element size of *3a*.

(4) In general, the rest of the crank is to be suitable for numeric stability of the solver.

(5) Drillings and holes for weight reduction have to be modelled.

(6) Submodeling may be used as long as the software requirements are fulfilled.

2.2 Material

In the FE analysis, material parameters such as Young's modulus (E) and Poisson's ratio (ν) are required, as primarily strain is calculated and stress is derived from strain through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel the following is advised: $E = 2.05 \times 10^5$ MPa and $\nu = 0.3$.

2.3 Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed.

(1) Principal -stresses criterion:

The quality of the mesh is to be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1, σ_2 and σ_3 the following criterion must be met:

$$\min\left(|\sigma_1|, |\sigma_2|, |\sigma_3|\right) < 0.03 \max\left(|\sigma_1|, |\sigma_2|, |\sigma_3|\right).$$

(2) Averaged/unaveraged -stresses criterion:

The averaged/unaveraged -stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF: unaveraged nodal stress results calculated from each element connected to a node i are to differ less than 5% from the 100% averaged nodal stress results at this node i at the location examined.

3 *Load cases and assessment of stress*

FE calculation is to be performed for the following load cases.

3.1 Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed. Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines, as shown in Figure III-3.1.

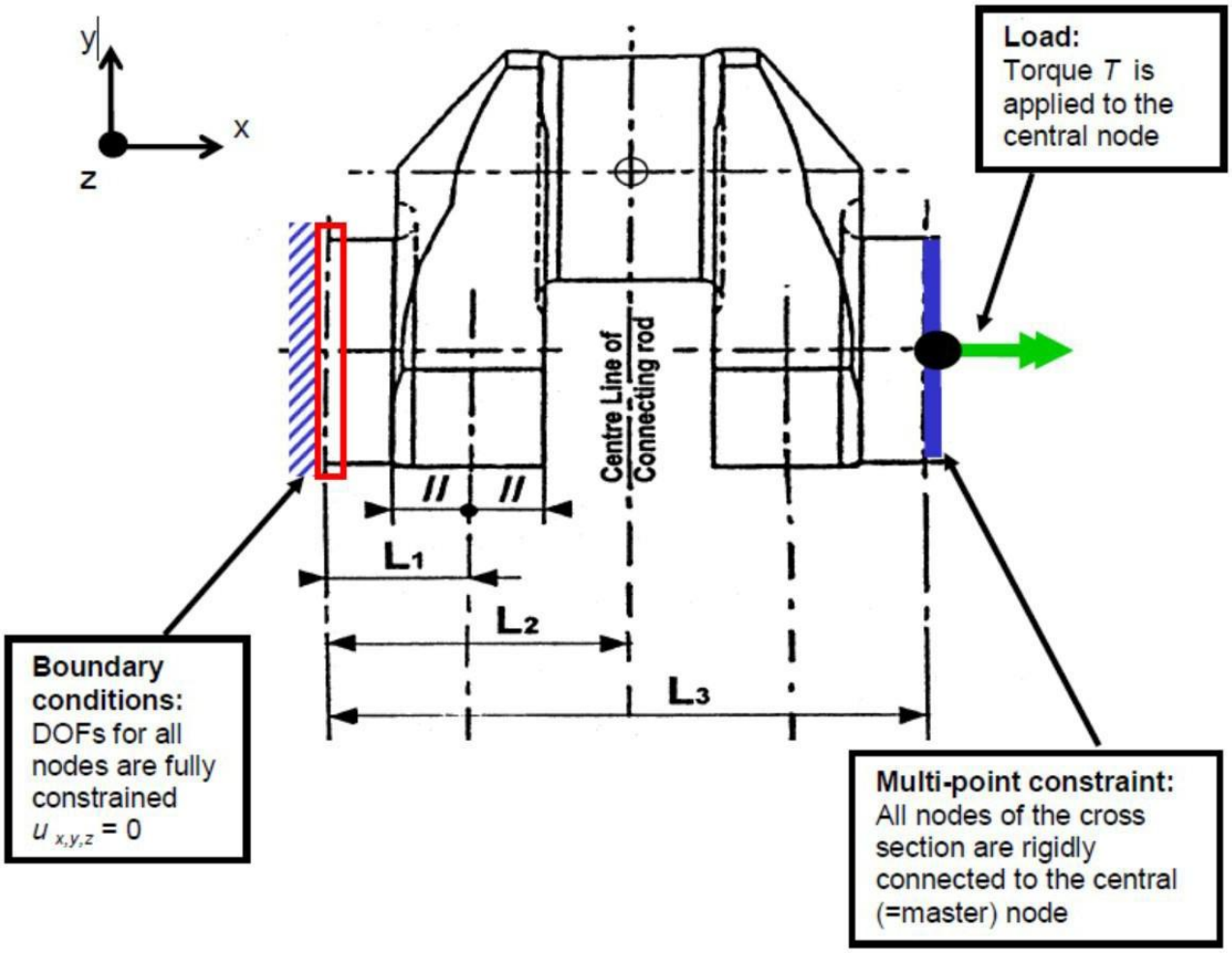


Figure III-3.1 Boundary and load conditions for the torsion load case

For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max\left(\left|\sigma_1\right|, \left|\sigma_2\right|, \left|\sigma_3\right|\right)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per 2.3.3 of this Appendix with torque T: $\tau_N = \frac{T}{W_P}$.

3.2 Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines, as shown in Figure III-3.2.

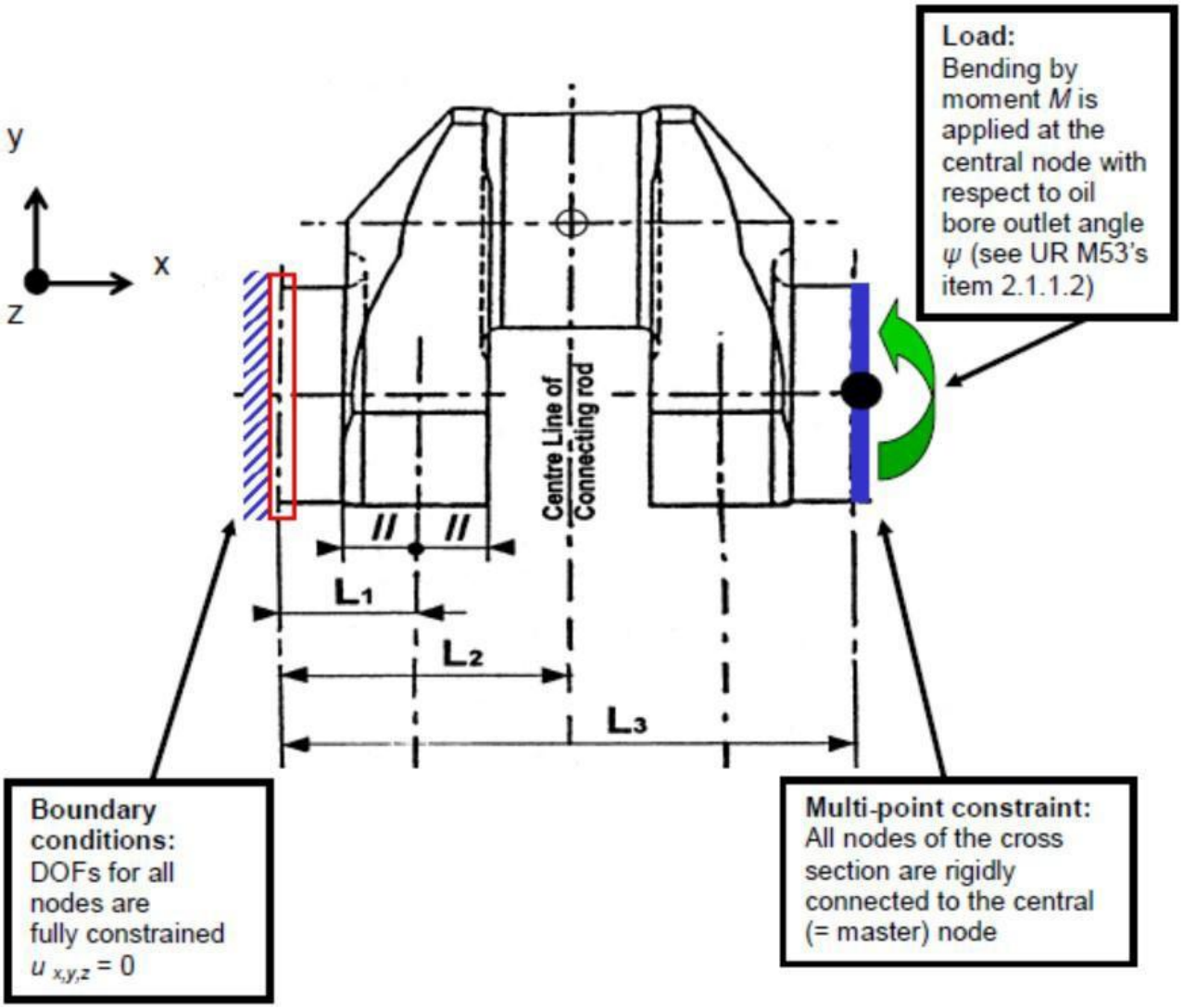


Figure III-3.2 Boundary and load conditions for the pure bending load case

For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max\left(\left|\sigma_1\right|, \left|\sigma_2\right|, \left|\sigma_3\right|\right)}{\sigma_{BON}}$$

where the nominal bending stress σ_{BON} referred to the crankpin is calculated per 2.3.1(3) of this Appendix with bending moment *M*: $\sigma_{BON} = \frac{M}{W_e}$.

Appendix 4 TYPE TEST OF DIESEL ENGINES

1 *General Requirements*

1.1 Application

1.1.1 The type testing, documented in this Appendix, is to be arranged to represent typical foreseen service load profiles, as specified by the engine builder, as well as to cover for required margins due to fatigue scatter and reasonably foreseen in-service deterioration.

1.1.2 This applies to:

(1) Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.;

(2) Parts subjected to low cycle fatigue (LCF) such as "hot" parts when load profiles such as idle − full load − idle (with steep ramps) are frequently used;

(3) Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

1.2 Safety precautions

1.2.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel, including crankcase explosive conditions protection, overspeed protection and any other shut down function, is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

1.2.2 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in 2.2.8 of this Appendix) is also to be carried out before the test runs.

1.2.3 Interlock test of turning gear is to be performed when installed.

1.3 Test program

1.3.1 The type testing is divided into 3 stages:

(1) Stage A − internal tests, including some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Rules or specified by the designer are to be presented to ISC before starting stage B;

(2) Stage B − witnessed tests, which are the testing made in the presence of the surveyor;

(3) Stage C − component inspection, which is the inspection of engine parts to the extent as rules required.

1.3.2 The complete type testing program is subject to approval by ISC. The extent of the surveyor's presence during each stage may be agreed by both sides, but at least during stage B and C.

1.3.3 Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

1.3.4 Upon completion of complete type testing (stage A through C), a type test report is to be submitted to ISC for review. The type test report is to contain:

(1) overall description of tests performed during stage A. Records are to be kept by the builder's QA management for presentation to ISC;

(2) detailed description of the load and functional tests conducted during stage B;

(3) inspection results from stage C.

1.3.5 As required in 1.1.2 of this Appendix, the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

1.3.6 High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in 9.10.2 of this Chapter.

Propulsion engines for high speed vessels that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle − full load − idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for reaching stable temperatures of the hot parts.

1.4 Measurements and recordings

1.4.1 During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

1.4.2 As a minimum, the following engine data are to be measured and recorded:
(1) engine r.p.m.;
(2) torque;
(3) maximum combustion pressure for each cylinder①;
(4) mean indicated pressure for each cylinder①;
(5) charging air pressure and temperature;
(6) exhaust gas temperature;
(7) fuel rack position or similar parameter related to engine load;
(8) turbocharger speed;
(9) all engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Note:

① For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented.

1.4.3 Calibration records for the instrumentation used to collect data as listed above are to be presented to- and reviewed by the attending Surveyor.
1.4.4 Additional measurements may be required in connection with the design assessment.

2 *Type Testing*

2.1 **Stage A − internal tests**

2.1.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval program.
2.1.2 At least the following conditions are to be tested:
(1) Normal case: The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.
(2) The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
(3) For high speed engines, the 100 h full load test and the low cycle fatigue test apply as required in connection with the design assessment.
(4) Specific tests of parts of the engine, required by ISC or specified by the designer.

2.2 **Stage B − witnessed tests**

2.2.1 The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.
2.2.2 The overspeed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.
2.2.3 Load test. The engine is to be operated according to the power and speed diagram (see Figure 2.2.3). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in 1.4 of this Appendix. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0.5 h can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.
The load points are:
(1) rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 h with data collection with an interval of 1 h. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test is to be made here;
(2) 100% power at maximum permissible speed corresponding to load point 2;
(3) maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (at least and normally 110%) and 103.2% speed according to the

nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes.
Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains;
(4) minimum permissible speed at 100% torque, corresponding to load point 4;
(5) minimum permissible speed at 90% torque corresponding to load point 5. (Applicable to propulsion engines only);
(6) part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine;
(7) crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.
2.2.4 During all these load points, engine parameters are to be within the specified and approved values.

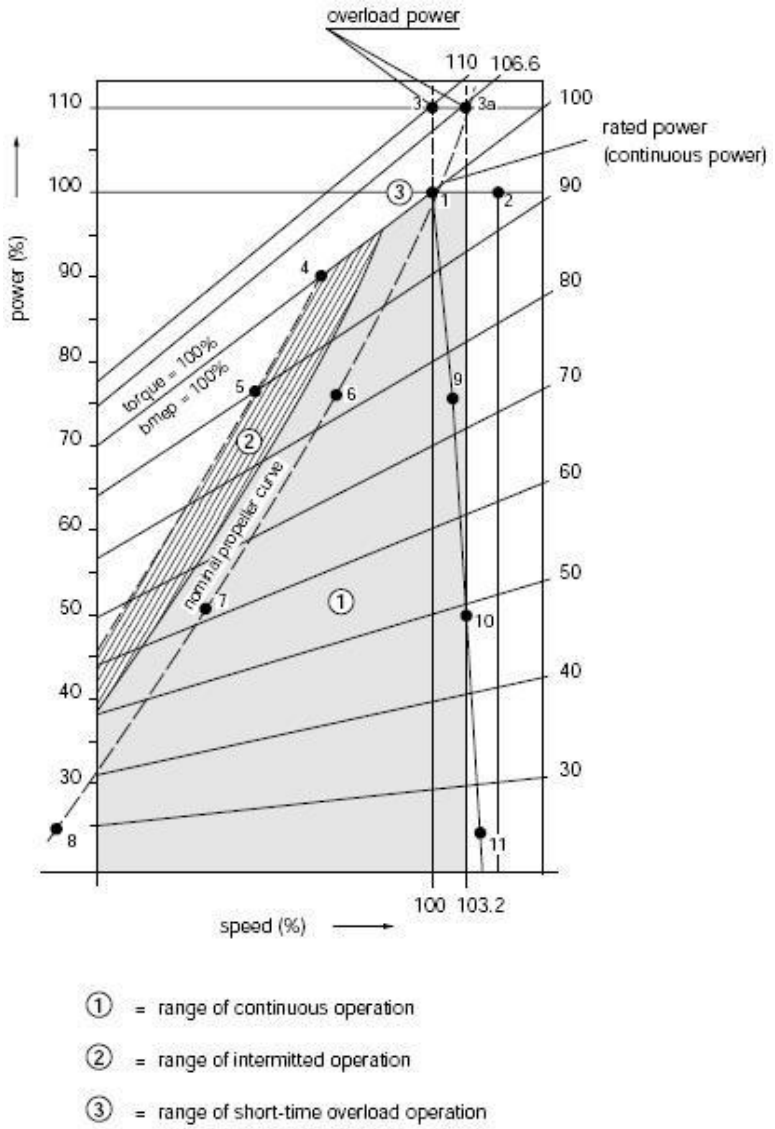


Figure 2.2.3 Diagram of power-speed

2.2.5 Operation with damaged turbocharger. For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage. Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor.

2.2.6 Functional tests are as follows:
(1) Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water-brake). During this operation, no alarm is to occur.
(2) Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
(3) Governor tests: tests for compliance with 9.7.8 and 9.7.10 of this Chapter are to be carried out.
2.2.7 Integration test. For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with ISC for selected cases based on the FMEA.
2.2.8 Fire protection measures. Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:
(1) The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
(2) Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by ISC. Readings obtained are to be randomly verified by use of contact thermometers.

2.3 Stage C − Opening up for Inspections
2.3.1 The crankshaft deflections are to be measured in the specified (by designer) condition.
2.3.2 High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.
2.3.3 For all the other engines, after the test run, the components are to be presented for inspection as follows:
(1) piston removed and dismantled;
(2) crosshead bearing dismantled;
(3) guide planes;
(4) connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides);
(5) main bearing dismantled;
(6) cylinder liner in the installed condition;
(7) cylinder head, valves disassembled;
(8) cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)
Note: Engines with long service experience from non-marine fields can have a reduced extent of opening.

2.3.4 One cylinder for in-line engines and two cylinders for V-engines are to be selected. For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.
2.3.5 Where deemed necessary by the surveyor, further dismantling of the engine may be required.

Appendix 5 APPROVAL AND CERTIFICATION OF DIESEL ENGINES

1 *General Provisions*

1.1 Scope

1.1.1 The approval and certification process of a diesel engine and the documents for use during manufacture and installation, and the document flow between engine designer, classification society approval center, engine builder/licensee and surveyors are provided in this Appendix.

1.1.2 The engine plans and documents are to be submitted for approval in accordance with the requirements of 9.1.12.1 and 9.1.12.2 of this Chapter.

1.2 *Definitions*

1.2.1 Definitions relating to approval and certification of diesel engines are given in Annex 1 of this Appendix.

1.3 *Type approval certificate*

1.3.1 For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are in 3.1 of this Appendix.

1.3.2 This process consists of the engine designer obtaining:

(1) drawing and specification approval;

(2) conformity of production;

(3) approval of type testing program;

(4) type testing of engines;

(5) review of the obtained type testing results;

(6) evaluation of the manufacturing arrangements;

(7) issue of a type approval certificate upon satisfactorily meeting the Rule requirements.

1.4 *Marine product certificate*

1.4.1 Each diesel engine manufactured for a shipboard application is to have a marine product certificate. The certification process details for obtaining the marine product certificate are in 3.2 of this Appendix.

1.4.2 This process consists of following steps:

(1) the engine builder/licensee obtaining design appraisal of the engine application specific documents;

(2) submitting a comparison list of the production drawings to the previously approved engine design drawings;

(3) forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary;

(4) engine testing; and

(5) upon satisfactorily meeting ISC Rule requirements, the issuance of an engine certificate.

1.5 *Approval of diesel engine components*

1.5.1 Components of engine designer's design which are covered by the type approval certificate of the relevant engine type are regarded as approved whether manufactured by the engine manufacturer or sub-supplied. For components of subcontractor's design, necessary approvals are to be obtained by the relevant suppliers (e.g. exhaust gas turbochargers, charge air coolers, etc.).

1.6 *Submission format of documentation*

1.6.1 The documentation is to be submitted to ISC in electronic or paper format. If the documentation is in paper format, it is to be submitted in triplicate.

2 *Document Flow for Diesel Engines*

2.1 Document flow for obtaining a type approval certificate

2.1.1 For the initial engine type, the engine designer prepares the documentation in accordance with requirements in 9.1.12.1 and 9.1.12.2 of this Chapter and forwards to ISC according to the agreed procedure for review.

2.1.2 Upon review and approval of the submitted documentation (evidence of approval), it is returned to

the engine designer.
2.1.3 The engine designer arranges for a surveyor to attend an engine type test and upon satisfactory testing ISC issues a type approval certificate.
2.1.4 A representative document flow process for obtaining a type approval certificate is shown in Annex 2 of this Appendix.

2.2 *Document flow for engine certificate*

2.2.1 The engine type must have a type approval certificate. For the first engine of a type, the type approval process and the engine certification process (ECP) may be performed simultaneously.
2.2.2 Engines to be installed in specific applications may require the engine designer/licensor to modify the design or performance requirements. The modified drawings are forwarded by the engine designer to the engine builder/licensee to develop production documentation for use in the engine manufacture in accordance with Table 1.
2.2.3 The engine builder/licensee develops a comparison list of the production documentation to the approval documentation. An example comparison list is provided in Annex 4. If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must obtain agreement to such differences from the licensor using the template in Annex 5.
If the designer acceptance is not confirmed, the engine is to be regarded as a different engine type and is to be subjected to the complete type approval process by the licensee.
2.2.4 The engine builder/licensee is to submit the comparison list and the production documentation to ISC according to the agreed procedure for review/approval.
2.2.5 ISC returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending surveyors. As the attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the Surveyors.
2.2.6 The attending Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.
2.2.7 The engine builder/licensee assembles the engine, tests the engine with a Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.
2.2.8 A representative document flow process for obtaining an engine certificate is shown in Figure 2, Annex 2 of this Appendix.

3 *Type Approval and Certification Process*

3.1 Type approval process

3.1.1 The type approval process consists of the steps in 3.1.2 to 3.1.5. The document flow for this process is shown in Figure 1, Annex 2 of this Appendix. The documentation, as far as applicable to the type of engine, to be submitted by the engine designer/licensor to ISC is listed in 9.1.12.1 and 9.1.12.2 of this Chapter.
3.1.2 9.1.12.2 lists basic descriptive information to provide the ISC an overview of the engine's design, engine characteristics and performance. Additionally, there are requirements related to auxiliary systems for the engine's design including installation arrangements, list of capacities, technical specifications and requirements, along with information needed for maintenance and operation of the engine.
3.1.3 9.1.12.1 lists the documents and drawings, which are to be approved by ISC.
3.1.4 Design appraisal (DA) is valid as long as no substantial modifications have been implemented. Where substantial modifications have been made, the validity of the DA's may be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations.
3.1.5 A type approval test is to be carried out in accordance with Appendix 4 of this Chapter and is to be witnessed by the attending surveyor. The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with Section 2 of this Chapter.
3.1.6 After the requirements in 3.1.2 through 3.1.5 have been satisfactorily completed, ISC issues a type approval certificate (TAC).
3.1.7 After the engine type has been approved for the first time, only those documents as listed in 9.1.12.1 and 9.1.12.2 of this Chapter, which have undergone substantive changes, will have to be resubmitted for consideration.
3.1.8 A renewal of type approval certificates will be granted upon submission of information in:
(1) the submission of modified documents or new documents with substantial modifications replacing

former documents compared to the previous submission(s) for DA; or
(2) a declaration that no substantial modifications have been applied since the last DA issued.
3.1.9 ISC reserves the right to limit the duration of validity of the type approval certificate. The type approval certificate will be invalid if there are substantial modifications in the design, in the manufacturing or control processes or in the characteristics of the materials unless approved in advance by ISC.
3.1.10 The assignment of documents to 9.1.12.2 for information does not preclude possible comments by ISC.
3.1.11 Where considered necessary, ISC may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing program.

3.2 *Certification process*

3.2.1 The certification process consists of the steps in 3.2.2 to 3.2.7. This process is illustrated in Figure 2, Annex 2 of this Appendix showing the document flows between the engine designer/licensor, engine builder/licensee, component manufacturers, classification society approval center and local offices.
For those cases when a licensor – licensee agreement does NOT apply, an "engine designer" is to be understood as the entity that has the design rights for the engine type or is delegated by the entity having the design rights to modify the design.
The documents listed in Table 1 of this Appendix may be submitted by the engine designer (licensor) or the manufacturer/licensee.
3.2.2 Prior to the start of the engine certification process, a design appraisal is to be obtained per 3.1.2 through 3.1.4 of this Appendix for each type of engine. Each type of engine is to be provided with a type approval certificate obtained by the engine designer/licensor prior to the engine builder/licensee beginning production manufacturing. For the first engine of a type, the type approval process and the certification process may be performed simultaneously.
The engine designer/licensor reviews the documents for the application and develops, if necessary, application specific documentation for the use of the engine builder/licensee in developing engine specific production documents.
If substantive changes have been made, the affected documents are to be resubmitted to ISC.
3.2.3 Table 1 lists the production documents, which are to be submitted by the engine builder/licensee to ISC following acceptance by the engine designer/licensor. The Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See 2.2.3 through 2.2.6 of this Appendix.
3.2.4 If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must provide to ISC approval center a "Confirmation of the licensor's acceptance of licensee's modifications" approved by the licensor and signed by licensee and licensor. Modifications applied by the licensee are to be provided with appropriate quality requirements. See Annex 5 of this Appendix for a sample format.
3.2.5 ISC carries out uniformity assessment on the manufacturer's production capability and quality control capability comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. Satisfactory conformance results in the issue of a class approval document.
3.2.6 In addition to the documents listed in Table 1, the engine builder/licensee is to be able to provide to the Surveyor performing the inspection upon request the relevant detail drawings, production quality control specifications and acceptance criteria. These documents are for supplemental purposes to the survey only.
3.2.7 Each engine assembly and testing procedure required according to the Rules are to be witnessed by the attending surveyor unless an Alternative Certification Scheme is agreed between manufacturer and ISC.

Documentation for the inspection of components and systems Table 1

No.	Item
1	Engine particulars as per data sheet in Annex 3
2	Material specifications of main parts with information on non-destructive material tests and pressure tests[1]
3	Bedplate, crankcase, frame, framebox, gearbox and thrust bearing bedplate of welded design, with welding details and welding instructions[2]
4	Crankshaft (including shaft coupling bolts, counterweights, including fastening), assembly and details, thrust shaft or intermediate shaft (if integral with engine)
5	Bolts and studs for main bearings, cylinder heads and exhaust valve (two stroke design) and connecting rods
6	Tie rods

No.	Item
7	Schematic layout or other equivalent documents on the engine of fuel oil system, lubricating oil system, cooling water system, starting air system and hydraulic system (for valve lift) [3]
8	Engine control and safety system
9	Shielding of high pressure fuel pipes, assembly[4]
10	Construction of accumulators for hydraulic oil and fuel oil
11	High pressure parts for fuel oil injection system[5]
12	Arrangement and details of the crankcase explosion relief valve[6]
13	Oil mist detection and/or alternative alarm arrangements
14	Cylinder head
15	Cylinder block, engine block
16	Cylinder liner
17	Counterweights (if not integral with crankshaft), including fastening
18	Connecting rod with cap, piston rod and crosshead
19	Piston, assembly[7]
20	Piston head
21	Camshaft drive, assembly[7]
22	Flywheel
23	Arrangement of foundation (for main engines only)
24	Fuel oil injection pump
25	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
26	Construction and arrangement of dampers
27	For electronically controlled engines, assembly drawings or arrangements of control valves, high-pressure pumps, drive for high pressure pumps and valve bodies, if applicable
28	Operation and service manuals[8]
29	Test program resulting from FMEA (for engine control system)[9]
30	Production specifications for castings and welding (sequence)
31	Type approval certification for environmental tests, control components[10]
32	Quality requirements for engine production

Notes:

1. For comparison with Rule requirements for material, NDT and pressure testing as applicable.
2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
3. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.
4. All engines.
5. The documentation to contain specifications for pressures, pipe dimensions and materials.
6. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
7. Including identification (e.g. drawing number) of components.
8. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
9. Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.
10. Documents modified for a specific application are to be submitted to the classification society for approval or information.

Annex 1 Glossary

Term	Definition
Acceptance criteria	A set of values or criteria which a design, product, service or process is required to conform with, in order to be considered in compliance
Accepted	Status of a design, product, service or process, which has been found to conform to specific acceptance criteria
Alternative Certification Scheme (ACS)	A system, by which a society evaluates a manufacturer's quality assurance and quality control arrangements for compliance with Rule requirements, then authorizes a manufacturer to undertake and witness testing normally required to be done in the presence of a Surveyor. It corresponds to ISC Type approval A.
Appraisal	Evaluation by a competent body
Approval	The granting of permission for a design, product, service or process to be used for a stated purpose under specific conditions based upon a satisfactory appraisal
Assembly	Equipment or a system made up of components or parts
Assess	Determine the degree of conformity of a design, product, service, process, system or organization with identified specifications, Rules, standards or other normative documents
Audit	Planned systematic and independent examination to determine whether the activities are documented, the documented activities are implemented, and the results meet the stated objectives
Auditor	Individual who has the qualifications and experience to perform audits
Certificate	A formal document attesting to the compliance of a design, product, service or process with acceptance criteria
Certification	A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria
Class approval	Approved by a Classification Society
Classification	Specific type of certification, which relates to the Rules of the relevant Classification Society
Competent body	Organization recognized as having appropriate knowledge and expertise in a specific area
Component	Part, member of equipment or system
Conformity	Where a design, product, process or service demonstrates compliance with its specific requirements
Contract	Agreement between two or more parties relating to the scope of service
Contractor	see Supplier
Customer	Party who purchases or receives goods or services from another
Design	All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product
Design analysis	Investigative methodology selectively used to assess the design
Design appraisal	Evaluation of all relevant plans, calculations and documents related to the design
Design review	Part of the appraisal process to evaluate specific aspects of the design
Drawings approval / plan approval	Part of the design appraisal process which relates to the evaluation of drawings and plans
Equipment	Part of a system assembled from components
Equivalent	An acceptable, no less effective alternative to specified criteria
Evaluation	Systematic examination of the extent to which a design, product, service or process satisfies specific criteria
Examination	Assessment by a competent person to determine compliance with requirements
Inspection	Examination of a design, product service or process by an Inspector
Inspection plan	List of tasks of inspection to be performed by the Inspector
Installation	The assembling and final placement of components, equipment and subsystems to permit operation of the system
Manufacturer	Party responsible for the manufacturing and quality of the product
Manufacturing process	Systematic series of actions directed towards manufacturing a product
Manufacturing process approval	Approval of the manufacturing process adopted by the manufacturer during production of a specific product
Material	Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product
Modification	A limited change that does not affect the current approval
Modification notice	Information about a design modification with new modification index or new drawing number replacing the earlier drawing
Performance test	Technical operation where a specific performance characteristic is determined

Term	Definition
Producer	See manufacturer
Product	Result of the manufacturing process
Prototype test	Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behavior
Quality assurance	All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to ISO 9001
Regulation	Rule or order issued by an executive authority or regulatory agency of a government and having the force of law
Repair	Restore to original or near original condition from the results of wear and tear or damages for a product or system in service
Requirement	Specified characteristics used for evaluation purposes
Information	Additional technical data or details supplementing the drawings requiring approval
Revision	Means to record changes in one or more particulars of design drawings or specifications
Specification	Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use
Substantive modifications or major modifications or major changes	Design modifications, which lead to alterations in the stress levels, operational behavior, fatigue life or an effect on other components or characteristics of importance such as emissions
Subsupplier/subcontractor	One who contracts to supply material to another supplier
Supplier	One who contracts to furnish materials or design, products, service or components to a customer or user
Test	A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure
Traceability	Ability to follow back through the design and manufacturing process to the origin
Type approval	The establishment of the acceptability of a product through the systematic: 1 evaluation of a design to determine conformance with specifications; 2 witnessing manufacture and testing of a type of product to determine compliance with the specification; 3 evaluation of the manufacturing arrangements to confirm that the product can be consistently produced in accordance with the specification
Type approval test	Last step of the type approval procedure. Test program in accordance with Appendix 4 of this Chapter
Witness	Individual physically present at a test and being able to record and give evidence about its outcome

Annex 2 Representative Document Flow Diagrams

The document flow diagrams are provided as an aid to all parties involved in the engine certification process as to their roles and responsibilities. Variations in the document flow may vary in response to unique issues with regard to various factors related to location, availability of components and surveys. In any case, the text in the Appendix takes precedence over these flow diagrams.

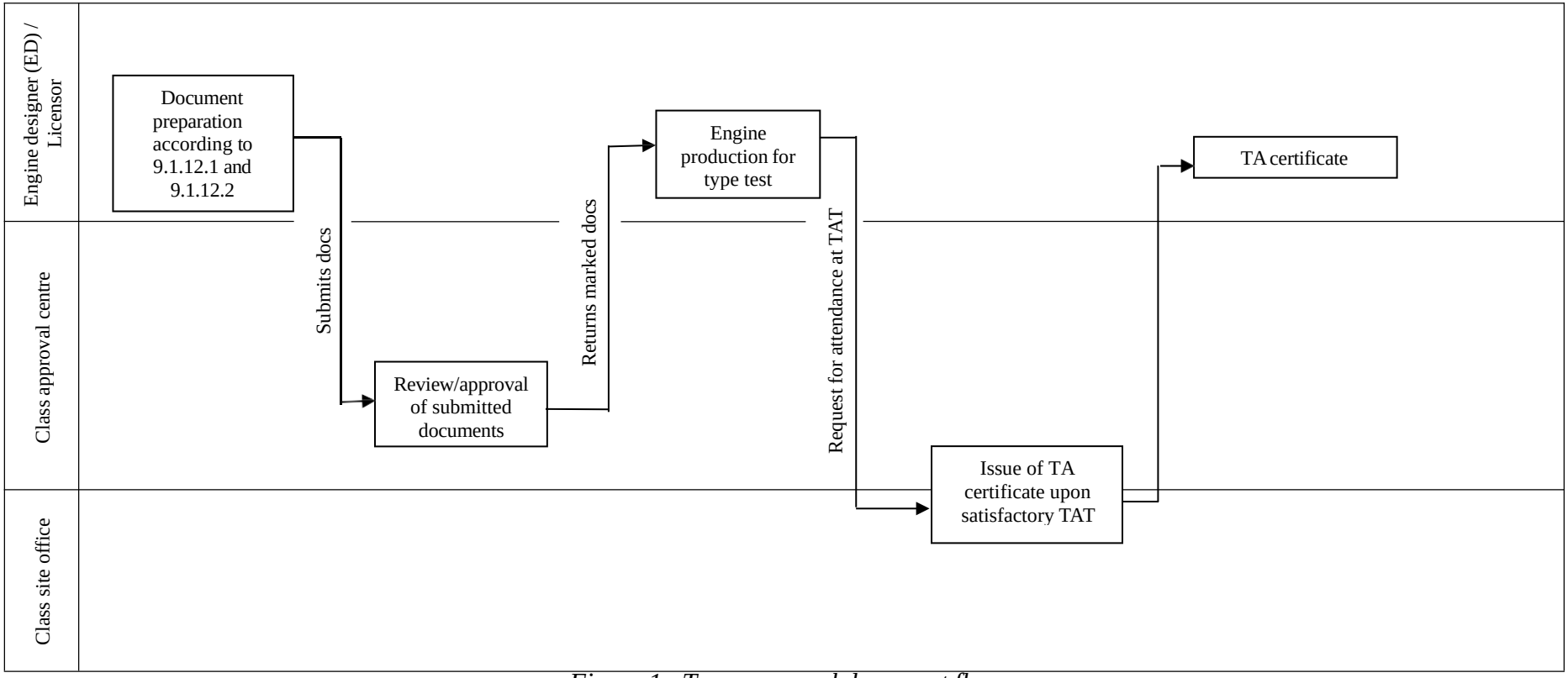


Figure 1 Type approval document flow

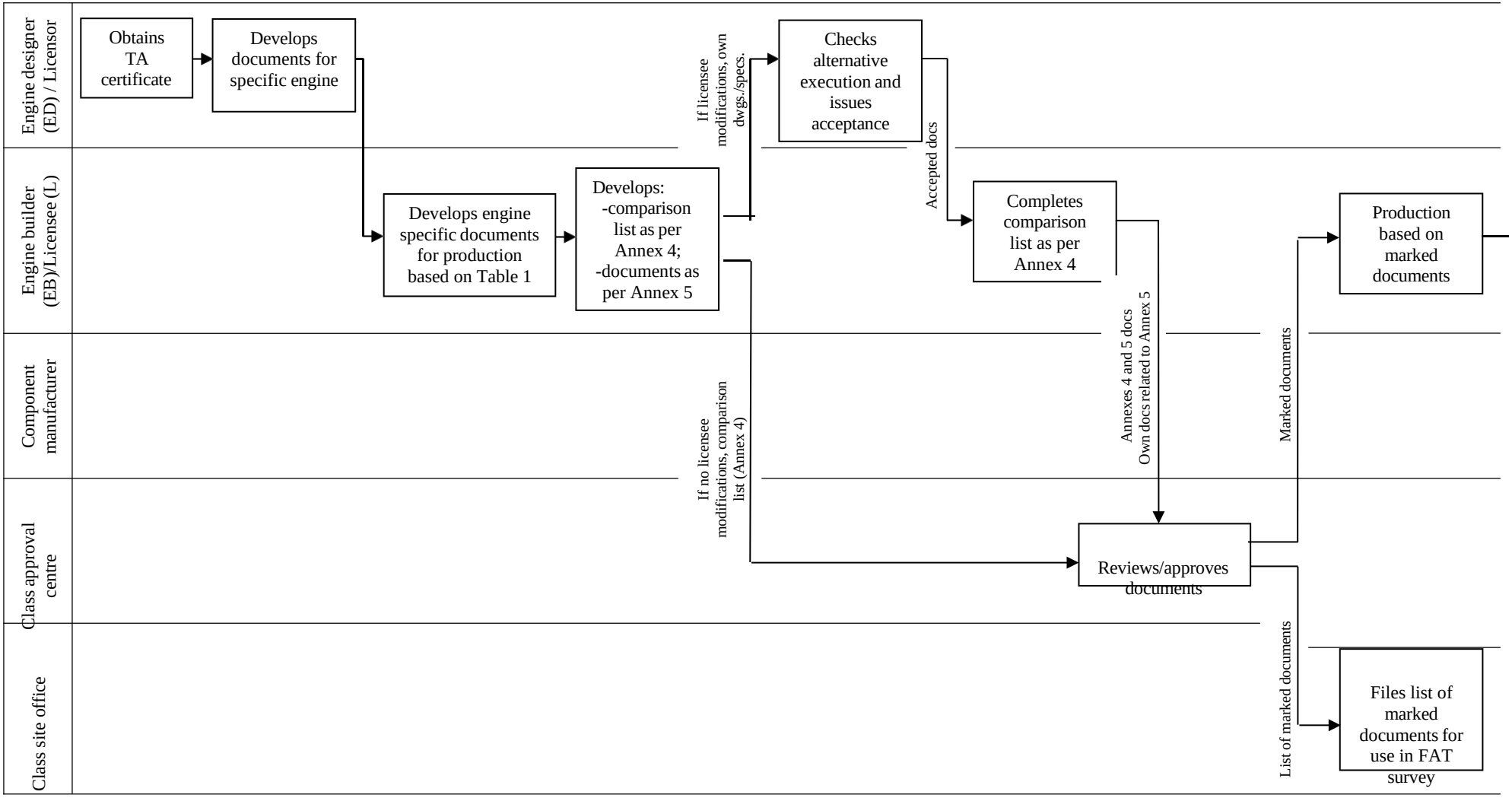


Figure 2 Engine certificate document flow

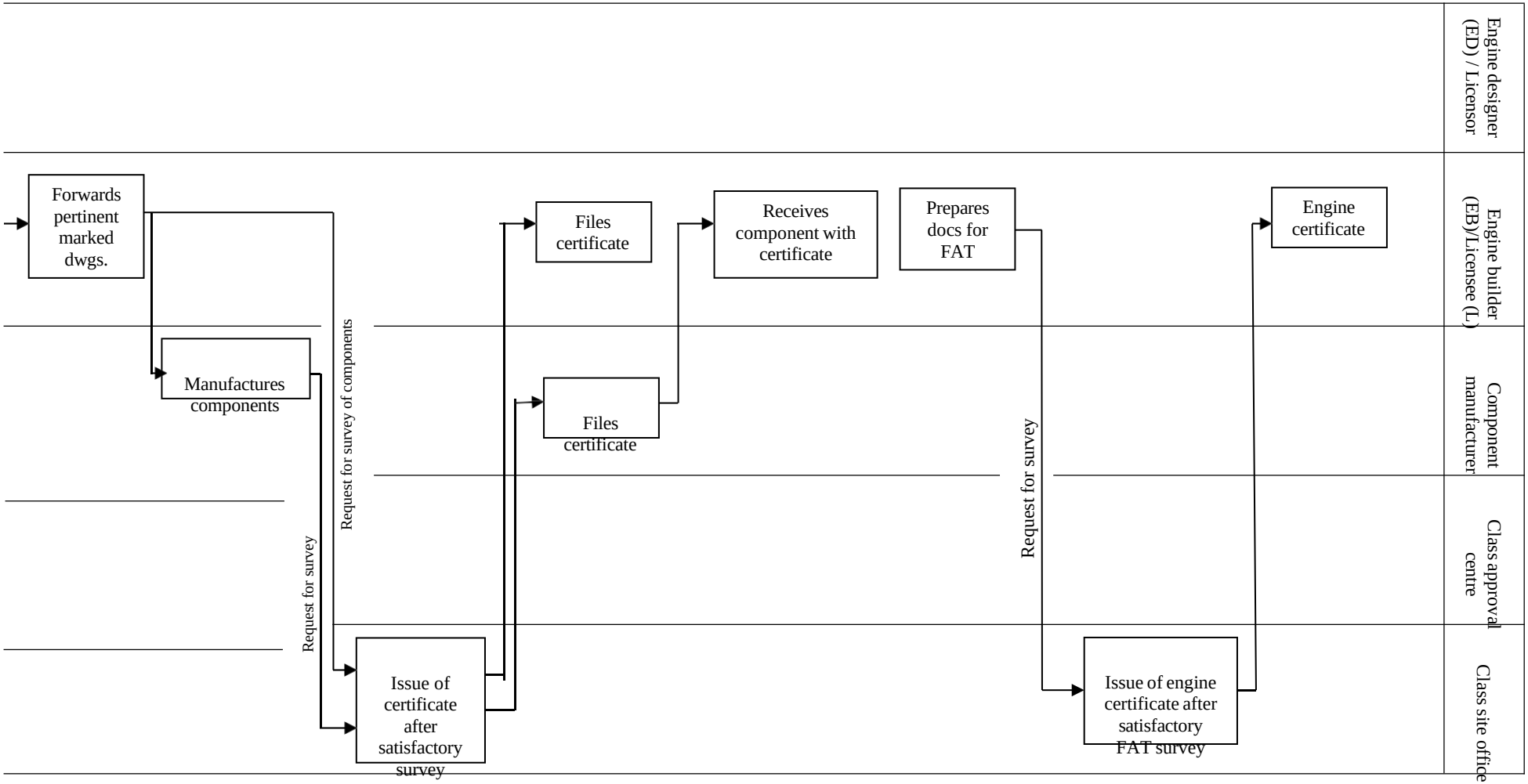


Figure 2 Engine certificate document flow (continued)

Annex 3 Internal Combustion Engine Approval Application Form and Data Sheet

ISC Application number (if applicable): Engine Manufacturer's Application Identification Number:

General Data	
Engine Designer: Contact Person: Address:	Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites① Name Country

1. Document purpose (select options from either 1a or 1b)	
1a. Type Approval Application	
Service Requested	Required activities②
☐ New Type Approval	• DA, TT, CoP
☐ Renew Type Approval	• CoP, if design change then amended or new certificate process to be followed
☐ Amend Type Approval	• DA & CoP, Further TT if previously approved engine has been substantively modified (as required by URM71)
☐ Design Evaluation	• DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated CoP has been completed.
☐ Update TA Supplement	• Update to Supplement, only for minor changes not affecting the Type Approval Certificate
☐ Other	• e.g. National/Statutory Administration requirements, i.e. MSC.81(70), as amended, for emergency engines
For TA Cert amendments or Supplement updates, details of what is to be changed:	
For 'Other', Details of the requirements to be considered:	
1b. Addendum for Individual Engine FAT and Certification	
☐ Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval application may be required.	
Reference number of Internal Combustion Engine Approval Application Form previously submitted and reference number of the Type Approval certificate	(Copy of original application form to be attached to this document)

2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Appraisal No. (if applicable)			
Formerly issued documentation for engine (E.g. previous type test reports, in-service experience justification reports, etc.)	Issuing Body:	Document Type:	Document No.:
Existing Certification (E.g. Manufacturer's quality certification ISO 9001 etc.)	Issuing Body	Document Type	Document No.

3. Design (mark all that apply)					
3a. Engine Particulars:					
Engine Type Manufactured Since③:			Number of delivered marine engines:		
Application	☐ Direct drive Propulsion (☐ Single engine / ☐ Multi-engine installation)		☐ Auxiliary (☐ Aux. Services / ☐ Electric Propulsion)		☐ Emergency
Mechanical Design	☐ 2-stroke ☐ Cross-head Cylinder bore(mm)	☐ 4-stroke ☐ Trunk-piston	☐ In-line ☐ Reversible Length of piston stroke (mm)	☐ Vee (V-angle °) ☐ Non-reversible	☐ Other ( )
Supercharging	☐ Without supercharging	☐ With supercharging ☐ Without charge air cooling ☐ Constant-pressure charging system		☐ With charge air cooling ☐ Pulsating pressure charging system	

① All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.

② DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See 'Definitions' at the end of this application form for more information.

③ Only in case of TA Extension.

Valve operation	☐ Cam control	☐ Electronic control		
Fuel Injection	☐ Direct injection	☐ Indirect injection	☐ Cam controlled injection	☐ Electronically controlled injection

Fuel Types (Classification according to ISO 8216)	☐ Marine residual fuel	cSt (Max. kinematic viscosity at 50°C)
	☐ Marine distillate fuel	DMA, DMB, DMC
	☐ Marine distillate fuel	DMX
	☐ Low flashpoint liquid fuel (specify fuel type)	
	☐ Gas (specify gas type)	
	☐ Other (specify)	
	☐ Dual Fuel (specify combinations of fuels to be used simultaneously)	

3b. Performance Data
(Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)

Model reference No. (if applicable)	
Max. continuous rating	kW/cyl
Rated speed	1/min
Mean indicated pressure	MPa
Mean effective pressure	MPa
Max. firing pressure	MPa
Charge air pressure	MPa
Compression ratio	-
Mean piston speed	m/s

3c. Crankshaft

Design	☐ Solid	☐ Semi-built	☐ Built	
Method of Manufacture	☐ Cast	☐ Forged		
		☐ Slab forged	☐ Approved die forged	☐ Continuous grain flow process

State approved forge/works name:

Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No

If yes, state process:

Crankshaft material specification:

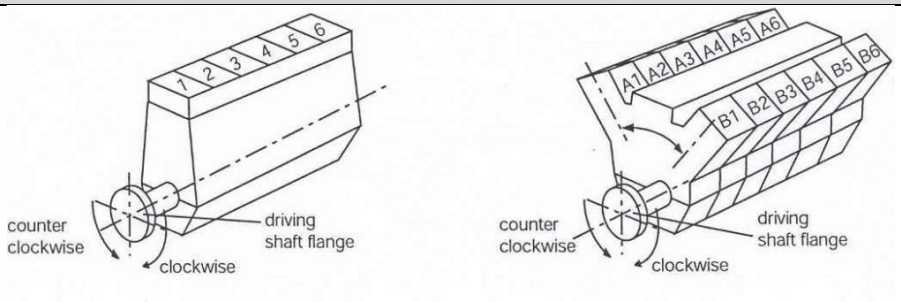
U.T.S. (N/mm^2) Yield strength (N/mm^2)

Hardness value (Brinell/Vickers) Elongation (%)

Dimensional Data

If shrunk on webs, state shrinkage allowance (mm)	Yield strength of crankweb material (N/mm^2)
Centre of gravity of connecting rod from large end centre (mm)	Radius of gyration of connecting rod (mm)
Mass of each crankweb (kg)	Centre of gravity of web from journal axis (mm)
Mass of each counterweight (kg)	Centre of gravity of each counterweight from journal axis (mm)
Axial length of main bearing (mm)	Main bearing working clearance (mm)
Mass of flywheel at driving end (kg)	Mass of flywheel at opposite end (kg)
Nominal alternating torsional stress in crankpin (N/mm^2)	Nominal alternating torsional stress in crank journal (N/mm^2)
Length between centres (Total length)(mm)	

3d. Firing order



State numbering system of cylinders from left to right as per above diagrams (as applicable)

Number of cylinders	Clockwise firing order	Counter-clockwise firing order

4. Engine Ancillary Systems

4a. Turbochargers ☐ Fitted ☐ Not Fitted

Turbocharger oil supply by: ☐ Engine lub. oil system ☐ TC internal lub. oil system

No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of TC	TC manufacturer & type	TC type approval certificate No.
				/ / / / / /	

4b. Speed governor

Engine application (Main/Aux/Emergency)	Manufacturer / type	Mode of operation	Type approval cert. No. (if electric / electronic gov.)
	/ / /		

4c. Overspeed protection

Independent overspeed protection available ☐ Yes ☐ No Mode of operation:

Manufacturer / type, if electronic: / Type approval certificate No.

4d. Electronic systems

Engine control and management system

Note: use Remarks section to identify when a different engine control system will be used for Type Test

Hardware: Manufacturer & Model: / Type approval certificate No.

Software: Name & Version: / Software conformity certificate No.

Additional electronic system 1: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 2: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 3: System function:

Manufacturer & type: / Type approval certificate No.

4e. Starting System

Type:

4f. Safety devices/functions

A flame arrestor or a bursting disk is installed in the starting air system: before each starting valve ☐ Yes ☐ No

in the starting air manifold ☐ Yes ☐ No

Crank case relief valves available ☐ Yes ☐ No Manufacturer / type: /

Type approval certificate No.

No. of cyl.	Total crankcase gross volume incl. attachments (m^3)	Type & size (mm) of relief valve	Relief area per relief valve (mm^2)	No. of relief valves
		/ / / /		

Method used for detection of potentially explosive crankcase condition:

☐ Oil mist detector: Manufacturer / type: / Type approval certificate No.

☐ Alternative method: (mark all that apply) ☐ crankcase pressure monitoring ☐ oil splash temperature monitoring ☐ bearing temperature monitoring ☐ recirculation arrangements ☐ other:

Cylinder overpressure warning device available ☐ Yes ☐ No

Type: Opening pressure (bar):

4g. Attached ancillary equipment(Mark all that apply)

Engine driven pumps:

☐ Main lubricating oil pump ☐ Sea cooling water pump ☐ LT-fresh cooling water pump

☐ HT-fresh cooling water pump ☐ Fuel oil booster pump ☐ Hydraulic oil pump ☐ Other ( )

Engine attached motor driven pumps:

☐ Lubricating oil pump ☐ Cooling fresh water pump ☐ Fuel oil booster pump

☐ Hydraulic oil pump ☐ Other ( )

Engine attached cooler or heater:

☐ Lubricating oil cooler ☐ Lubricating oil heater ☐ Fuel oil valve cooler

☐ Hydraulic oil cooler ☐ Cooling fresh water cooler

Engine attached filter:						
Lubricating oil filter	☐	Single	☐	Duplex	☐	Automatic
Fuel oil filter	☐	Single	☐	Duplex	☐	Automatic

5. Inclination limits (engine operation is safeguarded under the following limits)	Athwartships				Fore-and-aft			
	Static		Dynamic		Static		Dynamic	
Main & Auxiliary machinery	☐	15.0°	☐	22.5°	☐	5.0°	☐	7.5°
Emergency machinery	☐	22.5°	☐	22.5°	☐	10.0°	☐	10.0°
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals	☐	30.0°	☐	30.0°				

6. Main engine emergency operation				
At failure of one auxiliary blower, engine can be started and operated at partial load	☐	Yes	☐	No
At failure of one turbo charger, engine operation can be continued	☐	Yes	☐	No

7. References: Additional Information Attached to Application	
Document Name/Number	Summary of information contained in document

8. Further Remarks:

Completed By:

Company:

Job Title:

Date:

Signature: _____

Stamp:

Definitions:

(1) Design Appraisal: Evaluation of all relevant plans, calculations and documents related to the design to determine compliance with the individual Societies' technical requirements. This includes requirements for all associated ancillary equipment and systems essential for the safe operation of the engine, i.e. the Complete Engine. The Design Appraisal is recorded on a Supplement to the Type Approval Certificate.

(2) **Type Testing** requires satisfactory completion of testing of the Complete Engine against the requirements applicable engine Type Testing program. Type testing is only applicable to the first in series; all engines are to complete factory acceptance and shipboard trials as defined in Appendix 6 of this Chapter.

(3) **Design Approval Certification** may be granted upon satisfactory completion of Design Appraisal and Type Testing.

(4) **Assessment of Conformity of Production** means the assessment of quality assurance, manufacturing facilities and processes and testing facilities, to confirm the manufacturer's capability to repeatedly produce the complete engine in accordance with the approved and type tested design.

(5) **Type Approval Certification** will be granted upon satisfactory completion of Design Appraisal, Type Testing and assessment of Conformity of Production of the complete engine. The Type Approval Certificate will incorporate outputs from the Design Appraisal, the Type Test and the Assessment of Conformity of Production.

(6) **Complete Engine** includes the control system and all ancillary systems and equipment referred to in the Rules that are used for safe operation of the engine and for which there are rule requirements, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used may include, but are not limited to, the following:

① Turbocharger(s)
② Crank case explosion relief devices
③ Oil mist detection and alarm devices
④ Piping
⑤ Electronic monitoring and control system(s) – software and hardware

⑥ Fuel management system (where dual fuel arrangements are fitted)

⑦ Engine driven pumps

⑧ Engine mounted filters.

(7) Fuel Types: All fuels that the engine is designed to operate with are to be identified on the application form as this may impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel Types part of section 3a of this form.

Annex 4 Tabular Listing of Licensor's and Licensee's Drawing and Data

Licensee:_____ Licensor:_____

Licensee Engine No. :_____ Engine type:_____

No.	Components or System	Licensor			Licensee		Has Design been modified by Licensee?		If Yes, indicate following information	
		Dwg. No. & Title	Rev. No.	Date of Class Approval or Review	Dwg. No.	Rev. No.	Yes	No	Identification of Alternative approved by Licensor	Date of Class Approval or Review of Licensee Dwg.
1										
2										
3										
4										
5										
6										
7										
8										
9 ...										

I attest the above information to be correct and accurate.

Person in Charge (Licensee): _____ _____

Printed Name Signature

Date:_____

Annex 5 Sample Template for confirmation of the Licensor's Acceptance of Licensee's Modifications

<table>
<tr><td colspan="6">Engine Licensee Proposed Alternative to Licensor's Design</td></tr>
<tr><td colspan="6">Licensee information</td></tr>
<tr><td>Licensee:</td><td colspan="2"></td><td>Ref No.:</td><td colspan="2"></td></tr>
<tr><td>Description:</td><td colspan="2"></td><td>Info No.:</td><td colspan="2"></td></tr>
<tr><td>Engine type:</td><td colspan="2"></td><td>Main Section:</td><td colspan="2"></td></tr>
<tr><td>Engine No.:</td><td colspan="2"></td><td>Plant Id.:</td><td colspan="2"></td></tr>
<tr><td colspan="6">Design Spec: ☐ General ☐ Specific Nos:</td></tr>
<tr><td>Licensor design:</td><td colspan="3">State relevant part or drawing. numbers. Insert drawing clips or pictures.
Add any relevant information</td><td colspan="2">Licensee Proposed Alternative</td></tr>
<tr><td colspan="3"></td><td colspan="3">For example:
• Differences in geometry
• Differences in the functionality
• Material
• Hardness
• Surface condition
• Alternative standard
• Licensee production information introduced on the drawing
• Weldings or castings
• etc.</td></tr>
<tr><td>Reason:
☐ Licensee's production
☐ Sub-supplier's production
☐ Cost down
☐ Tools</td><td colspan="2">Interchangeability w. licensor design
☐ Yes ☐ No</td><td colspan="2">Non-conformity Report
Research, Assessment, Evaluation
☐ NCR ☐ RAE</td><td>Certified by licensee:
Initials:
Date:</td></tr>
<tr><td colspan="6">Licensor comments</td></tr>
<tr><td colspan="3">LoAE:
☐ Accepted as alternative execution (Licensor undertakes responsibility)
☐ No objection (Licensee undertakes responsibility)
☐ Not acceptable</td><td colspan="2">NCR:
☐ Approved
☐ Conditionally approved
☐ Rejected</td><td>Certified by licensor:
Initials:
Date:</td></tr>
<tr><td>Licensor ref.:</td><td colspan="4"></td><td>Date:</td></tr>
<tr><td>Licensee ref.:</td><td colspan="4"></td><td>Date:</td></tr>
</table>

Appendix 6 WORKS ACCEPTANCE TEST AND SHIPBOARD TRIALS OF DIESEL ENGINES①

1 *General Provisions*

1.1 Safety precautions

1.1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.

1.1.2 This applies especially to crankcase explosive conditions protection, but also to overspeed protection and any other shut down function.

1.1.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point is to be verified by the surveyor.

1.2 *General requirements*

1.2.1 Before any official testing, the engines are to be run-in as prescribed by the engine manufacturer.

1.2.2 Adequate test bed facilities for loads as required are to be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts.

1.2.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

1.2.4 Engines are to be inspected for:

(1) jacketing of high-pressure fuel oil lines including the system used for the detection of leakage;

(2) screening of pipe connections in piping containing flammable liquids;

(3) insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This is to be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, ISC may request temperature measurements as required by Appendix 4 of this Chapter.

1.2.5 These inspections are normally to be made during the works trials, but at the discretion of ISC, parts of these inspections may be postponed to the shipboard testing.

2 *Factory Acceptance Test*

2.1 Objectives

2.1.1 The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and functionality and to establish reference values or base lines for later reference in the operational phase.

2.2 *Records*

2.2.1 The following environmental test conditions are to be recorded:

(1) Ambient air temperature;

(2) Ambient air pressure;

(3) Atmospheric humidity.

2.2.2 For each required load point, the following parameters are normally to be recorded:

(1) Power and speed;

(2) Fuel index (or equivalent reading);

(3) Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement);

(4) Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in 9.6.2 of this Chapter);

(5) Charge air temperature;

(6) Charge air pressure;

(7) Turbocharger speed (to the extent that monitoring is required in 9.6.2 of this Chapter).

2.2.3 Calibration records for the instrumentation are, upon request, to be presented to the attending

---

① In this Appendix, the requirements for works acceptance test are applicable to diesel engines with an application for certification dated on or after 1 July 2016, and those for shipboard trials are applicable to diesel engines:
(1) with an application for certification dated on or after 1 July 2016; or
(2) installed on ships contracted for construction on or after 1 July 2016.

Surveyor.

2.2.4 For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

2.2.5 In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision are to be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 min.

2.3 *Test loads*

2.3.1 Test loads for various engine applications are given in 2.3.2 to 2.3.6.

2.3.2 Propulsion engines driving propeller or impeller only.

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed $1.032n_0$: Records to be taken after 15 min or after steady conditions have been reached, whichever is shorter.

Note: Only required once for each different engine/turbocharger configuration.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.

(5) Reversing manoeuvers (if applicable).

Note: After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by ISC. In that case, the fuel delivery system is to be blocked to that power.

2.3.3 Engines driving generators for electric propulsion:

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Governor tests for compliance with 9.7.8 and 9.7.10 of this Chapter are to be carried out.

(4) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and so that the protection system utilized in the electric distribution system can be activated before the engine stalls.

2.3.4 Engines driving generators for auxiliary purposes:

Tests are to be performed as in 2.3.3.

2.3.5 Propulsion engines also driving power take off (PTO) generator.

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_0, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

2.3.6 Engines driving auxiliaries

(1) 100% power (MCR) at corresponding speed n_0: at least 30 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

2.4 *Turbocharger matching with engine*

2.4.1 Turbochargers are to have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation. For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging is to occur.

Notes: Surging and continuous surging are defined as follows:

① Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.

② Continuous surging means that surging happens repeatedly and not only once.

2.4.2 Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

For 4-stroke engines, the following are to be performed without indication of surging:

− with maximum continuous power and speed (=100%), the speed is to be reduced with constant torque (fuel index) down to 90% power;

− with 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed is to be reduced to 72% while keeping constant torque (fuel index).

For 2-stroke engines, the surge margin is to be demonstrated by at least one of the following methods:

(1) The engine working characteristic established at workshop testing of the engine is to be plotted into the compressor chart of the turbocharger (established in a test rig). There is to be at least 10% surge margin in the full load range, i.e. working flow is to be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).

(2) Sudden fuel cut-off to at least one cylinder is not to result in continuous surging and the turbocharger is to be stabilized at the new load within 20 seconds. For applications with more than one turbocharger, the fuel is to be cut-off to the cylinders closest upstream to each turbocharger. This test is to be performed at two different engine loads:

− the maximum power permitted for one cylinder misfiring;

− the engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).

(3) No continuous surging and the turbocharger is to be stabilized at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

2.5 *Integration tests*

2.5.1 For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with ISC for selected cases based on the FMEA.

2.6 *Component inspections*

2.6.1 Random checks of components to be presented for inspection after works trials are left to the discretion of the surveyor.

3 *Shipboard Trials*

3.1 Objectives

3.1.1 The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine/shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

3.2 *Starting capacity*

3.2.1 Starting manoeuvers are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

3.3 *Monitoring and alarm system*

3.3.1 The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

3.4 *Test loads*

3.4.1 Test loads for various engine applications are given in 3.4.3 to 3.4.7. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

3.4.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

Note: Tests other than those listed in 3.4.3 to 3.4.7 may be required by statutory instruments (e.g. EEDI verification).

3.4.3 Propulsion engines driving fixed pitch propeller or impeller:

(1) At rated engine speed n_0: at least 4 h.

(2) At engine speed $1.032n_0$ (if engine adjustment permits, see 2.3.2 of this Appendix): 30 min.

(3) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer

(4) Minimum engine speed to be determined.

(5) The ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note: During stopping tests according to resolution MSC.137(76), see 3.5.1 for additional requirements in the case of a barred speed range.

3.4.4 Propulsion engines driving controllable pitch propellers:

(1) At rated engine speed n_0 with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 h.

(2) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(3) With reverse pitch suitable for manoeuvring, see 3.5.1 for additional requirements in the case of a barred speed range.

3.4.5 Engine(s) driving generator(s) for electrical propulsion and/or main power supply:

(1) At 100% power (rated electrical power of generator): at least 60 min.

(2) At 110% power (rated electrical power of generator): at least 10 min.

Note: Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 h. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.

(3) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in 9.7.10 of this Chapter.

3.4.6 Propulsion engines also driving power take off (PTO) generator:

(1) 100% engine power (MCR) at corresponding speed n_0: at least 4 h.

(2) 100% propeller branch power at engine speed n_0 (unless already covered in (1)): 2 h.

(3) 100% PTO branch power at engine speed n_0: at least 1 h.

3.4.7 Engines driving auxiliaries:

(1) 100% power (MCR) at corresponding speed n_0: at least 30 min.

(2) Approved intermittent overload: testing for duration as approved.

3.5 *Torsional vibrations*

3.5.1 Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times specified in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.

Note: Applies both for manual and automatic passing-through systems.

The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

Appendix 7 TYPE TESTING PROCEDURE FOR CRANKCASE EXPLOSION RELIEF VALVES

1 *Scope*

1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that relevant requirements of ISC are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

1.2 This test procedure is only applicable to explosion relief valves fitted with flame arresters.

Note: Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with this Appendix may be proposed by the manufacturer. The alternative testing arrangements are to be agreed by ISC.

2 *Applicable standards or rules*

2.1 ISO 16852.

2.2 ISO/IEC 17025.

2.3 ISO 12100.

2.4 VDI 3673-1.

2.5 IMO MSC/Circular 677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324.

3 *Purpose*

3.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(1) to verify the effectiveness of the flame arrester;

(2) to verify that the valve closes after an explosion;

(3) to verify that the valve is gas/air tight after an explosion;

(4) to establish the level of overpressure protection provided by the valve.

4 *Test facilities*

4.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements specified in 4.1.1 to 4.1.11.

4.1.1 The test houses where testing is carried out are to be accredited to a recognized national or international standard, e.g. ISO/IEC 17025, and are to be acceptable to ISC.

4.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.1.3 The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0.1%.

4.1.4 The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.

4.1.5 The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.

4.1.6 The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not “pipe like” with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.

4.1.7 The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.

4.1.8 A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

(1) outside diameter of 2 times the outer diameter of the valve top cover;

(2) internal bore having the same internal diameter as the valve to be tested.

4.1.9 The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.

4.1.10 The test vessel is to be provided with a means of fitting an ignition source at a position specified in 5.3 of this Appendix.

4.1.11 The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the relevant requirements in 9.7.4.6 of this Chapter for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume.

Notes:

① This means that the testing of a valve having 1,150 cm^2 of free area, would require a test vessel with a volume of 10 m^3.

② Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

③ In no case is the volume of the test vessel to vary by more than -10% to +15% from the design cm^2/m^3 volume ratio.

5 *Explosion test process*

5.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5%±0.5%. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

5.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0.5%.

5.3 The ignition of the methane and air mixture is to be made at the centerline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

5.4 The ignition is to be made using a maximum 100 J explosive charge.

6 *Valves to be tested*

6.1 The valves used for type testing (including testing specified in 6.3) are to be selected from the manufacturer's normal production line for such valves by the Surveyor witnessing the tests.

6.2 For approval of a specific valve size, three valves are to be tested in accordance with 6.3 and 7.1 to 7.2 of this Appendix. For approval of a series of valves, 9.1 to 9.4 of this Appendix are to be complied with.

6.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20% and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.

Note: This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

6.4 The type testing of valves is to recognize the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

7 *Method*

7.1 The following requirements of 7.1.1 to 7.1.5 are to be satisfied at explosion testing.

7.1.1 The explosion testing is to be witnessed by a Surveyor.

7.1.2 Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

7.1.3 Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.

7.1.4 The pressure rise and decay during all explosion testing is to be recorded.

7.1.5 The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

7.2 The explosion testing is to be in three stages as specified in 7.2.1 to 7.2.3 for each valve that is required to be approved as being type tested.

7.2.1 Stage 1: Two explosion tests are to be carried out in the test vessel with the circular plate described in 4.1.8 fitted and the opening in the plate covered by a 0.05 mm thick polythene film.

Note: These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, see 8.1.6 of this Appendix.

7.2.2 Stage 2:

(1) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e. in the vertical or horizontal position with the circular plate described in 4.1.8 located between the valve and pressure vessel mounting flange.

(2) The first of the two tests on each valve is to be carried out with a 0.05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test

vessel, enclosing the valve and circular plate. Before carrying out the explosion test, the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in 2.1 to 2.5 of this Appendix.

Note: During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

(3) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

(4) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

7.2.3 Stage 3: Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognizing that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

8 *Assessment and records*

8.1 For the purposes of verifying compliance with the requirements of this Appendix, the assessment and records of the valves used for explosion testing are to address the requirements as specified in 8.1.1 to 8.1.9.

8.1.1 The valves to be tested are to have evidence of design appraisal/approval by ISC witnessing tests.

8.1.2 The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.02 MPa.

8.1.3 The test vessel volume is to be determined and recorded.

8.1.4 For acceptance of the functioning of the flame arrester, there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.

8.1.5 The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

8.1.6 The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

8.1.7 The valve tightness is to be ascertained by verifying from the records at the time of testing that an underpressure of at least 0.3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

8.1.8 After each explosion test specified in 7.2.2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

8.1.9 After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

9 *Design series qualification*

9.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

9.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters subject to the following requirements being satisfied.

$$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

$$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where: n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1;

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2;

A_1 = free area of quenching device for a valve with a relief area equal to S_1;

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

9.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 7 and 8 of this Appendix can be evaluated, where valves are of identical type and have identical features of construction, in accordance with 9.3.1 to 9.3.3:

9.3.1 The free area of a larger valve does not exceed three times +5% that of the valve that has been satisfactorily tested.

9.3.2 One valve of the largest size, subject to 9.3.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2(1) and the volume of the test vessel is not to be less than one third of the volume required by 4.1.11.

9.3.3 The assessment and records are to be in accordance with Section 8 of this Appendix noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

9.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 of this Appendix can be evaluated, where valves are of identical type and have identical features of construction , in accordance with 9.4.1 to 9.4.3:

9.4.1 The free area of a smaller valve is not less than one third of the valve that has been satisfactorily tested.

9.4.2 One valve of the smallest size, subject to 9.4.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2(1) and the volume of the test vessel is not to be more than the volume required by 4.1.11.

9.4.3 The assessment and records are to be in accordance with Section 8 of this Appendix noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

10 *The report*

10.1 The test facility is to deliver a full report that includes the following information and documents specified in 10.1.1 to 10.1.8.

10.1.1 Test specification.

10.1.2 Details of test pressure vessel and valves tested.

10.1.3 The orientation in which the valve was tested (vertical or horizontal position).

10.1.4 Methane in air concentration for each test.

10.1.5 Ignition source.

10.1.6 Pressure curves for each test.

10.1.7 Video recordings of each valve test.

10.1.8 The assessment and records stated in Section 8 of this Appendix.

11 *Approval*

11.1 The approval of an explosion relief valve is at the discretion of ISC based on the appraisal plans and particulars and the test facility's report of the results of type testing.

Appendix 8 TYPE TESTING PROCEDURE FOR CRANKCASE OIL MIST DETECTION AND ALARM EQUIPMENT

1 *Scope*

1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy the requirements of ISC rules.

Note: This test procedure is also applicable to oil mist detection and alarm equipment intended for gear cases.

2 *Applicable standards or rules*

2.1 ISC Guidelines for Type Approval Test of Electric and Electronic Products, 2006.

3 *Purpose*

3.1 The purpose of type testing crankcase oil mist detection and alarm equipment is seven fold:

(1) to verify the functionality of the system;
(2) to verify the effectiveness of the oil mist detectors;
(3) to verify the accuracy of oil mist detectors;
(4) to verify the alarm set points;
(5) to verify time delays between oil mist leaving the source and alarm activation;
(6) to verify functional failure detection;
(7) to verify the influence of optical obscuration on detection.

4 *Test facilities*

4.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

(1) A full range of facilities for carrying out the environmental and functionality tests required by this procedure is to be available and be acceptable to ISC.

(2) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/*l* to an accuracy of ±10% in accordance with this procedure.

(3) When verifying the functionality, test houses are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. Use of low toxicity, low hazard oils as used in other applications is accepted, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified in this Appendix.

5 *Equipment testing*

5.1 The range of tests is to include the items specified in 5.1.1 to 5.1.2:

5.1.1 For the alarm/monitoring panel:

(1) functional tests described in 6.1 to 6.8 of this Appendix;
(2) electrical power supply failure test;
(3) power supply variation test;
(4) dry heat test;
(5) damp heat test;
(6) vibration test;
(7) EMC test;
(8) insulation resistance test;
(9) high voltage test;
(10) static and dynamic inclinations, if moving parts are contained.

5.1.2 For the detectors:

(1) functional tests described in 6.1 to 6.8 of this Appendix;
(2) electrical power supply failure test;
(3) power supply variation test;
(4) dry heat test;
(5) damp heat test;
(6) vibration test;
(7) EMC test where susceptible;
(8) insulation resistance test;
(9) high voltage test;

(10) static and dynamic inclinations.

6 *Functional tests*

6.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 6.2 to 6.6 with an oil mist concentration in air, known in terms of mg/*l* to an accuracy of ±10%.

6.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10%. See also 8.1.1.1 of this Appendix.

6.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of:

- between 0 and 10% of the lower explosive limit (LEL); or
- between 0 and *x*%, *x*% is a percentage of weight of oil in air determined by the manufacturer based on the sensor measurement method (e.g. obscuration or light scattering) that is acceptable to ISC taking into account the alarm level specified in 6.4.

Note: The LEL corresponds to an oil mist concentration of approximately 50 mg/*l* (4.1% weight of oil in air mixture).

6.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approximately 2.5 mg/*l*.

6.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

6.6 The performance of the detector which can measure and output the oil mist concentration, in mg/*l*, is to be demonstrated. This is to include the following:

(1) range;

(2) resolution;

(3) sensitivity.

Notes:

Sensitivity means quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.

Resolution means smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

6.7 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations. Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.

6.8 It is to be demonstrated that the openings of detector equipment does not become occluded or blocked under continuous splash and spray of engine lubricating oil, as may occur in the crankcase atmosphere. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by ISC. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.

6.9 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment and it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by ISC.

Note: This testing is in addition to that required by 5.1.2(5) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

6.10 It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

7 *Detectors and alarm equipment to be tested*

7.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the Surveyor witnessing the tests.

7.2 Two detectors are to be tested. One is to be tested in clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

8 *Method*

8.1 The following requirements are to be satisfied at type testing:

8.1.1 Oil mist generation is to satisfy 8.1.1.1 to 8.1.1.5.

8.1.1.1 The ambient temperature in and around the test chamber is to be at the standard atmospheric

conditions defined in ISC Guidelines for Type Approval Test of Electric and Electronic Products before any test run is started.

8.1.1.2 Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 μm. The oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1m and volume of not less than 1 m^3.

Note: The calculated oil droplet size using the sedimentation method represents the average droplet size.

8.1.1.3 The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. Where an alternative technique is used its equivalence is to be demonstrated.

Note: For this test, the gravimetric deterministic method is a process where the difference in weight of a 0.8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

8.1.1.4 Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

8.1.1.5 The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10% below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

8.1.1.6 The filters require to be weighed to a precision of 0.1 mg and the volume of air/oil mist sampled to 10 m*l*.

8.1.2 For type approval by ISC, the testing is to be witnessed by the Surveyor or authorised personnel from ISC.

8.1.3 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

8.1.4 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks classification approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

9 *Assessment*

9.1 Assessment of oil mist detection equipment after testing is to address the requirements specified in 9.1.1 to 9.1.3.

9.1.1 The equipment to be tested is to have evidence of design appraisal/approval by ISC witnessing tests.

9.1.2 Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings, and the maximum percentage level of lens obscuration.

9.1.3 After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

10 *Design series qualification*

10.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. An application and related information are to be submitted for confirmation.

11 *The report*

11.1 The test house is to provide a full report which includes the information specified in 11.1.1 to 11.1.3.

11.1.1 Test specification.

11.1.2 Details of equipment tested.

11.1.3 Results of tests, including a declaration by the manufacturer of the oil mist detector of its performance, accuracy and precision of oil mist concentration in air, range, resolution, response time, sensitivity, obscuration of sensor detection, declared as percentage of obscuration (0% totally clean, 100% totally obscure) and detector failure alarm.

12 *Acceptance*

12.1 Acceptance of crankcase oil mist detection equipment is at the discretion of ISC based on the

appraisal plans and particulars and the test house report of the results of type testing.

12.2 The plans and information specified in 12.2.1 to 12.2.4 are to be submitted for acceptance of oil mist detection equipment and alarm arrangements:

12.2.1 Description of oil mist detection equipment and system including alarms.

12.2.2 Copy of the test house report identified in 11.1 of this Appendix.

12.2.3 Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

12.2.4 Maintenance and test manual which is to include the following information:

(1) intended use of equipment and its operation;

(2) functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified;

(3) maintenance routines and spare parts recommendations;

(4) limit setting and instructions for safe limit levels;

(5) where necessary, details of configurations in which the equipment is and is not to be used.

Appendix 9 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL

1 *Scope*

1.1 This Appendix specifies testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

2 *Definitions*

2.1 Definitions addressing gas as fuel as given in Appendix 1 Safety of Low Pressure Gas Fuel Engines of this Chapter, apply.

2.2 Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

3 *Documents*

3.1 Prior to testing, the following documentation for the ERD shall be submitted for approval:

(1) drawings (sectional drawings, details, assembly etc.);

(2) specification data sheet including operating conditions and design limits such as:

① maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure;

② maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature;

③ static opening pressure, resulting from maximum charging air or exhaust gas back pressure;

④ maximum explosion pressure, i.e. maximum pressure that the device can withstand;

⑤ geometric relief area;

(3) product marking;

(4) installation and operation manual;

(5) test program;

(6) specification of test vessel.

4 *Tests*

4.1 Test specimens

4.1.1 The ERD used for the explosion test is to be selected from the manufacturer's production line by ISC:

(1) as a finished certified component itself, or

(2) on samples taken from earlier stages in the production of the component, when applicable.

4.1.2 If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

4.1.3 If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:

(1) kind of ERD (valve, rupture disc, etc.);

(2) mounting orientation (vertical, horizontal);

(3) design of ERD (e.g., spring design, sealing);

(4) design of flame arrester;

(5) ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in 4.3.2 of this Appendix.

4.1.4 The selection of the representative ERD is subject to approval by the ISC.

4.2 Demonstration of opening pressure

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the

ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

4.3 Explosion test

4.3.1 Test facility

4.3.1.1 The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025, and are to be acceptable to the ISC.

4.3.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.3.1.3 The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ±0.1%.

4.3.1.4 The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

4.3.1.5 The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

4.3.1.6 The explosion test (Para 4.3.5 of this Appendix) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

4.3.2 Test vessel

4.3.2.1 The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

4.3.2.2 The test vessel shall comply with the following requirements:

(1) The shape of the test vessel is to correspond to a pipe with $L/D \geq 10$.

(2) The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be ± 10% of the static opening pressure of the ERD.

(3) The volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ± 15%.

(4) The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.

(5) The ignition is to be made at the middle of the test vessel.

(6) The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.

(7) The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.

(8) The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in Para 4.3.6 of this Appendix.

(9) The test vessel configuration is subject to approval by ISC.

4.3.2.3 Typical test vessel configurations:

As shown in Figures 4.3.2.3(1) to 4.3.2.3(3), all test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel (↯). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).



Figure 4.3.2.3(1) Configuration without ERD (flanges for ERDs closed (2))



Figure 4.3.2.3(2) Configuration with ERD (3) mounted at the front end of the test vessel

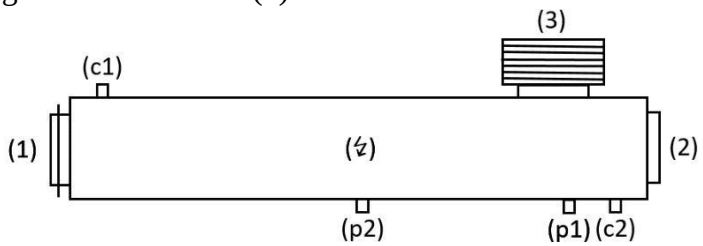


Figure 4.3.2.3(3) Configuration with ERD (3) mounted on top of the test vessel

4.3.3 Explosion test process

4.3.3.1 The explosion testing is to be performed in two stages according to 4.3.4 and 4.3.5 of this Appendix for each ERD that is required to be approved as type tested.

4.3.3.2 The explosion testing is to be witnessed by a Society surveyor.

4.3.3.3 Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

4.3.4 Reference test – Explosion test without ERD

4.3.4.1 Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Figure 4.3.2.3(1) of this Appendix.

4.3.4.2 The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

4.3.5 ERD test – Explosion test with ERD

4.3.5.1 Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

4.3.5.2 If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted. The test vessel configuration is shown in Figure 4.3.2.3(2) or 4.3.2.3(3).

4.3.6 Explosion test method

4.3.6.1 The test conditions shall comply with the intended use of the ERD, such as:

(1) pipe diameter;

(2) operating pressure;

(3) operating temperature;

(4) installation orientation.

4.3.6.2 All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

4.3.6.3 The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

4.3.6.4 The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

4.3.6.5 If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

4.3.6.6 The ignition is to be made using an explosive charge of 50 - 100 Joule.

4.3.6.7 Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

4.3.6.8 The pressure rise and decay during all explosion testing is to be recorded.

4.3.6.9 The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (4.3.4 of this Appendix) and the average of the two explosions of the ERD test (4.3.5 of this Appendix).

4.3.6.10 For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (4.3.5 of this Appendix). This is to be monitored by a high-speed video camera (4.3.1 of this Appendix), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

4.3.6.11 After each ERD test (4.3.5 of this Appendix), the external condition of the flame arrester to be

examined for signs of damage and/or deformation that may affect the operation of the ERD.

4.4 Check of ERD components

4.4.1 After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

5 *Test report*

5.1 A complete test report has to be submitted to ISC for:
(1) the demonstration of opening pressure (4.2 of this Appendix);
(2) the explosion test (4.3 of this Appendix).
5.2 The reports shall include respective information according to the requirements in 4 of this Appendix, as applicable:
(1) test specimens;
(2) test facility, including measuring equipment and test vessel;
(3) measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.);
(4) video documentation of explosion tests;
(5) photo documentation of ERD components.

6 *Assessment*

6.1 To verify compliance with this requirement the assessment has to address the following:
6.1.1 Function and mechanical integrity of the ERD.
(1) After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
(2) If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
(3) The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in 4.3.5 of this Appendix.
6.1.2 The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

7 *Approval*

7.1 The approval of an ERD is at the discretion of individual classification societies based on the appraisal of plans and particulars and the test report of type testing.
7.2 The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in 4.3.2 of this Appendix for the test vessel rupture disc in terms of free area.

Appendix 10 SAFETY OF METHANOL/ETHANOL FUEL ENGINES

1 *General Requirements*

1.1 Application and scope

1.1.1 This Appendix applies to engines supplied with methanol/ethanol as fuel. This Appendix only specifies relevant requirements for the use of methanol/ethanol fuel, and in addition, methanol/ethanol fuel engines are to comply with relevant provisions of this Chapter.

1.1.2 Methanol/ethanol fuel engines can be either dual fuel engines or methanol/ethanol fuel only engines. Methanol/ethanol fuel can be introduced as follows:

(1) cylinder air inlet channel port; or

(2) cylinder direct injection.

The methanol/ethanol and air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

1.1.3 This Appendix covers the following applications, but is not limited to:

(1) mechanical propulsion;

(2) generating sets intended for main propulsion and auxiliary applications;

(3) single engine or multi-engine installations.

1.1.4 For fuel only engines, applicable requirements of this Appendix can be determined in consultation with ISC.

1.2 *Definitions*

(1) Dual fuel engine means an engine that can burn methanol/ethanol as fuel simultaneously with liquid diesel fuel, either as pilot oil or bigger amount of liquid diesel fuel (methanol/ethanol mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

(2) Fuel only engine means an engine capable of operating on methanol/ethanol fuel only and not able to switch over to oil fuel operation.

(3) Methanol/ethanol fuel engine means either a methanol/ethanol fuel only engine or a dual fuel engine.

(4) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the methanol/ethanol and air mixture on dual fuel engines.

(5) Methanol/ethanol fuel valve unit is a set of valves and fittings used to control the methanol/ethanol fuel supply to each engine, which is used to control or adjust the methanol/ethanol fuel supply before the engine.

(6) Recognized standards mean applicable international or national standards acceptable to ISC or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.

(7) Safety Concept is a document describing the safety philosophy with regard to methanol/ethanol as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 *Plans and documents*

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.1 of this Chapter :

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of methanol/ethanol fuel system on the engine
(2)	Methanol/ethanol piping system (including double-walled arrangement where applicable)
(3)	Parts for methanol/ethanol admission system②
(4)	Arrangement of explosion relief valves (crankcase①, charge air manifold, exhaust gas manifold) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine (only for dual fuel engine)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for dual fuel engine)
(8)	High pressure parts for pilot fuel oil injection system②(only for dual fuel engine)
(9)	Ignition system (only for fuel only engine)

Note:
① If required by 9.1.12 of this Chapter.
② The documentation to contain specification of pressures, pipe dimensions and materials.

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of methanol/ethanol fuel engines, in addition to those required in 9.1.12.2 of this Chapter:

No.	Plans and documents
(1)	Safety concept
(2)	Report of the risk analysis①
(3)	Methanol/ethanol specification
(4)	Other plans and documents as deemed necessary by ISC

Note:
① see 1.4 of this Appendix.

1.4 *Risk analysis*

1.4.1 The risk analysis is to address:

(1) a failure or malfunction of any system or component involved in the methanol/ethanol operation of the engine;

(2) a fuel leakage downstream of the methanol/ethanol valve unit;

(3) the safety of the engine in case of emergency shutdown or blackout, when running on methanol/ethanol;

(4) the inter-actions between the methanol/ethanol fuel system and the engine.

Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.

1.4.2 The risk analysis is to be carried out in accordance with international standard ISO 31010: Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 The risk analysis is to:

(1) Identify all the possible failures in the concerned equipment and systems which could lead:

① to the presence of methanol/ethanol in components or locations not designed for such purpose, and/or

② to ignition, fire or explosion.

(2) Evaluate the consequences.

(3) Where necessary, identify the failure detection method.

(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems:

(1) failure of the methanol/ethanol-related systems or components, in particular methanol/ethanol piping and cylinder methanol/ethanol supply valves etc. Failures of the methanol/ethanol supply components not located directly on the engine, are not to be considered in the analysis;

(2) failure of the ignition system (oil fuel pilot injection or sparking plugs);

(3) failure of the methanol/ethanol combustion or abnormal combustion (misfiring, knocking);

(4) failure of the engine monitoring, control and safety systems;

Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with 9.1.12.2(23) and Note 5 of this Chapter.

(5) changes of operating modes for dual fuel engines, including fuel oil mode, methanol/ethanol fuel mode and other working mode;

(6) hazard potential for crankcase methanol/ethanol fuel accumulation, for engines where the space below the piston is in direct communication with the crankcase.

2 *Design Requirements*

2.1 General principles

2.1.1 The manufacturer is to declare the methanol/ethanol fuel for the engine.

2.1.2 Components containing or likely to contain methanol/ethanol are to be designed to:

(1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;

(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked methanol/ethanol in the most severe condition or the fitting of suitable pressure relief devices of an approved type.

Note:

① Discharge from pressure relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.

② Relief devices are to be fitted with a flame arrester.

2.2 *Design requirements*

2.2.1 A means is to be provided to monitor and detect poor combustion or misfiring in the engine. In the event that it is detected, continued operation may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.

Engine components through which methanol/ethanol fuel may flow are to be effectively sealed to prevent leakage of fuel into the machinery space.

2.2.2 Engine-mounted methanol/ethanol pipes are to be designed in accordance with the methanol/ethanol pipe requirements (e.g. wall thickness, allowable stress, material, pipe manufacture and connection etc.) in Chapter 3 of ISC Guidelines for Ships Using Methanol/Ethanol Fuel and the arrangement is to satisfy the following requirements:

(1) Pipes and equipment containing methanol/ethanol fuel are defined as hazardous area Zone 0. The space between the methanol/ethanol fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1.

(2) Methanol/ethanol fuel fuel piping is to be arranged for gas freeing and purging.

(3) The arrangement and installation of methanol/ethanol fuel piping are to provide the necessary flexibility to accommodate the sway or vibration of the engine and prevent fatigue damage at the connection between the piping and the engine.

2.2.3 Charge air system on the engine

(1) The charge air system on the engine is to be designed in accordance with 2.1.2 above.

(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).

2.2.4 Exhaust system on the engine

(1) The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.

(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

(3) Each methanol/ethanol engine is to be provided with independent exhaust system.

2.2.5 For engines where the space below the piston is in direct communication with the crankcase, protection of crankcase is also to comply with the following requirements:

(1) Detailed assessment is to be carried out to hazard potential for crankcase gas accumulation.

(2) For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

2.2.6 Control, monitoring, alarm and safety systems

(1) The engine control system is to be independent and separate from the safety system.

(2) The methanol/ethanol supply valves are to be controlled by the engine control system or by the engine methanol/ethanol demand.

(3) Combustion is to be monitored on an individual cylinder basis.

(4) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

(5) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for dual fuel or fuel only engines are to be provided in accordance with Table 1 of this Appendix in addition to the general monitoring and safety system functions given by the Rules.

Note: For dual fuel engines, Table 1 applies only to the methanol/ethanol mode.

Monitoring and Safety System Functions for Methanol/Ethanol Fuel Engines

Table 1

Parameter	Alarm	Automatic activation of the engine block valve	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the methanol/ethanol fuel supply line	×	×	×	× ⑤
Methanol/ethanol fuel supply systems - malfunction	×	×	×	× ⑤
Pilot fuel injection or spark ignition systems - malfunction	×	× ②	×	× ②⑤
Exhaust gas temperature after each cylinder - high	×	× ②	×	×②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	× ②	×	× ②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	× ②④	× ④	× ②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×
Pressure in the crankcase – high ④ (for engines where the space below the piston is in direct communication with the crankcase)	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the methanol/ethanol fuel block valve	×	×	×	

Symbol: × Applicable

Note:

① Dual fuel engine only, when running in methanol/ethanol mode.

② For fuel only engines, the block valve and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.

③ Required only if necessary for the detection of misfiring.

④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.

⑤ Fuel only engine only.

⑥ Where required by 9.7.6 of this Chapter.

3 Specific Design Requirements

3.1 Dual fuel engines

3.1.1 The maximum continuous power that a dual fuel engine can develop in methanol/ethanol mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the methanol/ethanol quality. This maximum power available in methanol/ethanol mode and the corresponding conditions are to be stated by the engine manufacturer and demonstrated during the type test. The 110% load tests are not required in the methanol/ethanol mode of dual fuel engines when 4.1.4, 4.2.1 and 4.3 of this Appendix are implemented in accordance with the provisions in 1.3 of Appendix 4, 2.3 and 3.4 of Appendix 6 of this Chapter.

3.1.2 Dual fuel engines are to be arranged to use either oil fuel or methanol/ethanol fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from methanol/ethanol use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply. Changeover to methanol/ethanol fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from methanol/ethanol fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to methanol/ethanol operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the methanol/ethanol supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Methanol/ethanol supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.1.4 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

3.2 *Fuel only engines*

3.2.1 In case of ignition failure of the ignition system, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder methanol/ethanol supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.2.2 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

4 *Type Testing, Factory Acceptance Tests and Shipboard Trials*

4.1 Type Testing

4.1.1 Type approval of dual fuel and fuel only engines is to be carried out in accordance with 9.10.1 and 9.10.2 of this Chapter, taking into account the additional requirements below.

4.1.2 In addition to the criteria given in 9.1.2.1(1) of this Chapter, the type of engine is defined by the following:

(1) methanol/ethanol admission method (direct cylinder injection, cylinder intake channel injection etc.);

(2) methanol/ethanol supply valve operation (mechanical or electronically controlled);

(3) ignition system (pilot injection, spark ignition etc.);

(4) ignition system (mechanical or electronically controlled).

4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4 of this Chapter, measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4 of this Chapter. For dual fuel engines, the load tests are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this Appendix).

4.1.5 In addition to the measurements and records required in 1.4, Appendix 4 of this Chapter, the following engine data are to be measured and recorded:

(1) Each fuel index for methanol/ethanol and diesel as applicable (or equivalent reading).

(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.

Additional measurements may be required in connection with the design assessment.

4.1.6 In addition to internal tests required in 2.1, Appendix 4 of this Chapter, the following conditions are to be tested:

(1) dual fuel engines are to run the load points in both methanol/ethanol and diesel modes (with and without pilot injection in service) as found applicable for the engine type.

(2) for dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.

4.1.7 Witnessed tests are to be carried out in accordance with 2.2, Appendix 4 of this Chapter. The following requirements are to be considered:

(1) The following test conditions are to be considered for dual fuel engine during the load test:

① All load points must be run in both methanol/ethanol and diesel modes that apply for the engine type as defined by the engine designer. This also applies to the overspeed test.

(2) The following items are to be carried out for functional test:

① For dual fuel engines, the lowest specified speed is to be verified in diesel mode and methanol/ethanol mode.

② For dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.

③ The efficiency of the ventilation arrangement of the double walled piping system is to be verified.

④ Simulation of a methanol/ethanol leakage in way of a cylinder methanol/ethanol supply valve.

Engines intended to produce electrical power are to be tested as follows:

① Capability to take sudden load and loss of load in accordance with the provisions of 9.7.10.1 of this Chapter.

Notes:

1. For dual fuel engines, switchover to oil fuel during the test is acceptable.

2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1 of this Chapter.

(3) Fuel only and dual fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with ISC for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;

② Failure of a cylinder methanol/ethanol supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal methanol/ethanol pressure;

⑤ Abnormal methanol/ethanol temperature*.

Note*: This test may be carried out using a simulation signal of the temperature.

4.1.8 Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4 of this Chapter. The components to be inspected after the test run are to include also:

(1) methanol/ethanol supply valve;

(2) pilot fuel injection valve/spark igniter.

4.2 *Factory acceptance test*

4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6 of this Chapter, taking into account the additional requirements below.

For dual fuel engines, the load tests referred to in 2.3, Appendix 6 of this Chapter are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this Appendix).

4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6 of this Chapter , measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.2.3 In addition to the records required in 2.2, Appendix 6 of this Chapter, the following engine data are to be recorded:

(1) Fuel index, both methanol/ethanol and diesel as applicable (or equivalent reading);

(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.

4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6 of this Chapter. Dual fuel engines are to be tested in both diesel and methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Methanol/ethanol fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with ISC for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;

② Failure of a cylinder methanol/ethanol supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal methanol/ethanol pressure;

⑤ Abnormal methanol/ethanol temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by ISC.

4.3 *Shipboard trials*

4.3.1 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6 of this Chapter. For dual fuel engines, the test loads are to be carried out in all operating modes (methanol/ethanol mode, diesel mode, etc.). For dual fuel engines, when load tests specified in 3.4, Appendix 6 of this Chapter are carried out in methanol/ethanol mode, test loads are taken as each percentage of the maximum output power in methanol/ethanol mode (see 3.1.1 of this Appendix).

CHAPTER 10 TRANSMISSION GEARING

Section 1 GENERAL PROVISIONS

10.1.1 General requirements

10.1.1.1 The requirements of this Chapter are applicable to transmission gearing for main propulsion machinery and driving auxiliary machinery where the transmitted power is equal to or more than 100 kW.

10.1.1.2 The certification requirements and inspection of products for transmission gearing are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.

10.1.2 *Strengthening for navigation in ice*

10.1.2.1 In the case of ships strengthened in ice, the transmission gearing of main propulsion systems is to comply with the relevant requirements in Chapter 14 of this PART.

10.1.3 *Vibration and alignment*

10.1.3.1 For the requirements for vibration and alignment of the transmission gearing, see Chapter 12 of this PART.

10.1.4 *Plans and documents*

10.1.4.1 Following plans and documents are to be submitted for approval:

(1) General arrangement (longitudinal and transverse sections);

(2) Details of pinions and wheels, including ring gear, where applicable, and parameters necessary for calculation of load capacity;

(3) Gear shafts;

(4) Bosses, if any;

(5) Clutches and/or couplings;

(6) Other power transmitting parts;

(7) Gear casing, incl. propeller thrust bearing housing, if any;

(8) Basic sizes of the tooth profile of the tools;

(9) Calculations of the load capacity of gears;

(10) Strength calculations of shafts;

(11) Strength calculations of clutches and/or couplings;

(12) Calculation of combined dynamic reaction forces and its acting direction of sliding bearings for gearboxes;

(13) Details of heat treatment of gears;

(14) Details of gear materials;

(15) Details of weld procedures for gears or gearbox, if any;

(16) Plans and documents for gear box lubricating and cooling systems;

(17) Diagram of the hydraulic system, if applicable;

(18) Other plans and documents deemed necessary by ISC.

Section 2 MATERIALS

10.2.1 *Material properties*

10.2.1.1 Shafts, gear, wheel's rim, if any, couplings, etc. of the transmission gearing are to be made of steel forgings, and the materials for forgings are to be in accordance with the relevant requirements of ISC Rules for Materials and Welding.

10.2.1.2 For gears of through-hardened steels, provision is to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified tensile strength of the wheel material is not to be more than 85% of that of the pinion.

10.2.1.3 The full specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

10.2.1.4 Where it is proposed to use alloy steel forgings, the chemical composition and mechanical properties are to comply with relevant requirements of ISC Rules for Materials and Welding.

10.2.2 *Non-destructive tests*

10.2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

10.2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

Section 3 DESIGN AND CONSTRUCTION

10.3.1 *Design*

10.3.1.1 Appraisal of gear strength is to comply with the requirements of "Appraisal of gear strength" in Appendix 1 of this Chapter. For the enclosed reduction transmission gearing used for main propulsion machinery where the maximum continuous transmitted power is less than 220 kW and for essential auxiliary machinery where the maximum continuous transmitted power is less than 110 kW, the calculation of load capacity of gears need not satisfy the requirements of this Chapter.

10.3.2 *Tooth form*

10.3.2.1 The roots of teeth are to be formed with smooth fillets of radius not less than 0.25 m_n.

10.3.2.2 Where the ratio of working length over the gear faces to reference diameter of pinion exceeds 1.5, the ends of the teeth are to be chamfered.

10.3.2.3 The teeth of pinions and wheels are to be suitably relieved on flanks in cases where any of the following conditions applies:

(1) normal module of teeth exceeds 6 mm;

(2) addendum of pinion teeth exceeds 65% of total working depth of engagement;

(3) ratio of total working depth of engagement to normal pitch of teeth exceeds 0.75.

10.3.3 *Tooth surface*

10.3.3.1 The hardened layer of the surface-hardened gear is to be distributed over and extended to the whole tooth surfaces and fillets.

10.3.3.2 For nitrided gear, generally, the depth of nitrided layer is not to be less than 0.40 mm.

10.3.3.3 For surface-hardened gears (except the nitrided) the depth of hardened layer is not to be less than 0.15 m_n.

10.3.3.4 For carburized gears, the surface hardness is generally not to be less than HRC 58.

10.3.4 *Gear*

10.3.4.1 The grade of accuracy of gear cutting is not to be less than 7 for diesel engines and 6 for turbines.

10.3.4.2 Where bolts or shrink-fit are used to secure the side plates to rim and boss of the wheels, the bolts are to be tight fit in holes and the nuts are to be suitably locked.

10.3.5 *Gear shafts*

10.3.5.1 The diameter d of the quill shafts is not to be less than the value obtained from the following formula:

$$d = 100 \sqrt[3]{\frac{400 N_e}{n_e R_m}} \quad \text{mm}$$

where: N_e — the maximum continuous output transmitted by the shaft, in kW;

n_e — speed of the shaft at N_e, in r/min;

R_m — minimum tensile strength of shaft material, in N/mm^2, but not exceeding 1,100 N/mm^2.

10.3.5.2 The diameter of gear shafts is to be calculated in accordance with 11.2.2 of this PART.

10.3.5.3 Where the gear is fitted on the gear shaft by key or shrink-fit, the diameter of gear shafts at the fitting area is to be increased by 5% over the value determined in 10.3.5.2.

10.3.5.4 Where the wheel shaft is driven by only one pinion or by two pinions arranged to subtend an angle at the centre of the shaft of less than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 15% over the value determined by 10.3.5.2. Where it is driven by two pinions arranged to subtend an angle at the centre of the shaft of more than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 10% over the value determined in 10.3.5.2.

10.3.6 *Gear casings*

10.3.6.1 Gear casings of welded construction are to be stress-relief heat treated on completion of welding

in accordance with the relevant requirements of ISC Rules for Materials and Welding.

10.3.6.2 Gear casings are to be of sufficient strength and rigidity, and are to be provided with inspection openings and adequate venting devices.

10.3.6.3 Where thrust bearing is provided inside the gear casing, the latter is to be adequately strengthened.

10.3.7 *Connections*

10.3.7.1 Where the coupling of the output shaft is fitted by means of the oil pressure injection method, the actual shrinkage allowance δ is to comply with the requirements of 11.3.2.3 of this PART; where shrink-fit is employed, 0.03 in the formula may be ignored.

10.3.7.2 For the shrink-fit of rim to boss, boss to shaft and the shrink-fit of other items, a safety factor against slippage in design is not to be less than $2.8C$, where C is a coefficient having the following values:

$C = 1$ for gears driven by turbines or electric motors and gears driven through a hydraulic, electromagnetic or high elasticity coupling;

$C =$ 1.2 in other cases.

10.3.7.3 Clutches and couplings in the transmission gearing are to comply with the requirements of Section 3, Chapter 11 of this PART.

10.3.8 *Grade of Meshing*

10.3.8.1 Tooth faces are to be evenly meshed. For diesel or turbine transmission gearing, the contact marking is not to be less than Grade 7 or Grade 6 respectively.

10.3.9 *Reversal*

10.3.9.1 For reversible gearing:

(1) the speed at free clutching and declutching is not to be less than 50% of the rated speed;

(2) the time required for reversal is not to be more than 15 s;

(3) sufficient astern power is to be available.

10.3.10 *Lubricating and cooling*

10.3.10.1 The construction and arrangement of lubricating oil and cooling systems of transmission gearing are to be in accordance with the requirements of 1.2.1.1 of this PART.

10.3.10.2 Lubricating oil is to be efficiently conveyed to all bearings, meshed gears and other portions requiring lubrication. The arrangement of oil pockets of sliding bearings is to be such that the effect of combined dynamic force of bearings is taken into account.

10.3.10.3 The lubricating oil system of transmission gearing for diesel engines is to be independent.

10.3.10.4 The lubricating oil pump for the transmission gearing is to comply with the requirements in 4.6.1, Chapter 4 of this PART.

10.3.10.5 Thermometers and pressure gauges are to be provided in the pressure lubricating oil systems, and working oil pressure gauge is to be fitted in addition when hydraulic system is employed. An oil level indicator is to be provided for the oil sump of splash lubrication.

10.3.10.6 Where the lubricating oil for the transmission gearing is circulated under pressure, provision is to be made for efficient filtration of the oil. The filters are to comply with the relevant provisions of 4.6.2.2 of this PART.

10.3.10.7 The lubricating oil temperature in the transmission gearing is not to exceed 70℃, and not to exceed 80℃ if roller bearing is fitted.

10.3.10.8 Cooling pipes passing through gear casings are not to have any detachable joint.

10.3.11 *Alarm*

10.3.11.1 Transmission gearing is to be fitted with alarm devices for low pressure of lubricating oil and in addition, an alarm device for high temperature of lubricating oil is to be fitted in case of transmission gearing whose input power is more than 1,470 kW.

10.3.12 *Emergency devices*

10.3.12.1 For hydraulically controlled transmission gearing in single screw ships, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of hydraulic control systems.

10.3.13 *Markings*

10.3.13.1 For reversible gearing, the directions of lever or handwheel for ahead and astern running are to

be marked at control station. As a common practice, to push the lever forward or to turn the handwheel clockwise is the way to move the ship ahead.

Section 4 TESTS

10.4.1 *Material tests*

10.4.1.1 Chemical composition and material test are to comply with the relevant requirements in ISC Rules for Materials and Welding.

10.4.2 *Balance tests*

10.4.2.1 All pinion and gear wheels are to be statically balanced. Where the linear velocity at the reference circle exceeds 25 m/s, dynamic balance test is to be made. Driven parts of the coupling are to be attached to the gear before balancing.

The residual dynamic unbalance is not to exceed:

$\frac{6.0m}{n}\times10^2$ N·mm, for transmission gearing of diesel engines;

$\frac{2.4m}{n}\times10^2$ N·mm, for transmission gearing of turbines.

where: m — mass of components, in kg;

n — maximum working speed of components, in r/min.

10.4.2.2 Balance test may, however, be omitted for diesel engine gearing, provided that the rotating components are of solid forged construction or have a solid forged centre with shrunk-on rim, and in both cases are machined to give a concentric and uniform cross-section.

10.4.3 *Gear mesh tests*

10.4.3.1 Gear mesh tests are to be carried out and gear contact spots are not to be less than the value in Table 10.4.3.1.

Contact spots *Table 10.4.3.1*

Contact spots	Grade of accuracy			
	6	7	8	9
Not less than (%) according to height	50	45	40	30
Not less than (%) according to length	70	60	50	40

10.4.4 Bench trials

10.4.4.1 The transmission gearing is to be tested according to the test programs approved by ISC during bench trials.

Appendix 1 APPRAISAL OF GEAR STRENGTH

1 *General*

1.1 **Application**

1.1.1 This Appendix is applicable to the enclosed gears intended for main propulsion and for essential auxiliary services of ships and mobile offshore units, which accumulate a large number of load cycles (several millions), whose gear set is intended to transmit a maximum continuous power equal to, or greater than 220 kW for gears intended for main propulsion and 110 kW for gears intended for essential auxiliary services. These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above.

1.1.2 This Appendix is applicable to strength appraisal of involute spur and helical gears having parallel axis, and of bevel gears having transverse contact ratio $\varepsilon_{va} < 2$ for equivalent cylindrical gear.

1.1.3 This Appendix includes general, tooth surface contact stress, tooth root bending stress and alignment of gearbox shafting. All influence factors are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. These factors are to be calculated in accordance with the equations provided. Other factors, which are approximations, can be calculated according to methods acceptable to ISC.

1.2 Symbol, name and unit

1.2.1 The main symbols used in this Appendix are listed below. Other symbols introduced in connection with the definition of influence factors are described in the appropriate sections.

a — centre distance, in mm;
b — common face width, in mm;
$b_{1,2}$ — face width of pinion, wheel, in mm;
b_e — effective face width, in mm;
$d_{1,2}$ — reference diameter of pinion, wheel, in mm;
$d_{a1,2}$ — tip diameter of pinion, wheel, in mm;
$d_{b1,2}$ — base diameter of pinion, wheel, in mm;
$d_{f1,2}$ — root diameter of pinion, wheel, in mm;
$d_{w1,2}$ — working pitch diameter of pinion, wheel, in mm;
$d_{e1,2}$ — out pitch diameter of pinion, wheel, in mm;
F_t — nominal tangential load, in N;
$h_{1,2}$ — tooth depth, in mm;
$h_{a1,2}$ — addendum, in mm;
$h_{f1,2}$ — dedendum, in mm;
h_{ao} — addendum of cutter, in mm;
$h_{F1,2}$ — bending moment arm for load acting at the outer point of single tooth pair contact for pinion, wheel, in mm;
HV — Vickers hardness;
HRC — Rockwell hardness;
HB — Brinell hardness;
m_n — normal module, in mm;
$n_{1,2}$ — rotational speed of pinion, wheel, in r/min;
N_L — number of load cycles;
P — maximum continuous power or nominal power transmitted by the gear set (determined according to purpose), in kW;
P_{ro} — protuberance of tool, in mm;
P_{bt} — plane base terminal, in mm;
q_s — base circle parameter;
R_a — arithmetic mean of roughness, in μm;
R_z — mean peak-to-valley roughness, in μm;
S_{Fn} — tooth root chord in the critical section, in mm;
$T_{1,2}$ — torque in way of pinion, wheel, in N·m;
u — gear ratio;
V — linear velocity at pitch diameter, in m/s;
x — addendum modification coefficient of pinion, wheel;
$x_{hm1,2}$ — profile shift coefficient (midface);

$x_{sm1,2}$ — tooth thickness modification coefficient (midface);
$z_{1,2}$ — number of teeth;
$z_{n1,2}$ — virtual number of teeth;
$\alpha_{Fen1,2}$ — normal pressure angle relevant to direction of application of load at the outer point of single pair tooth contact of pinion, wheel, in °;
α_{pro} — cutter boss angle, in °;
α_n — normal pressure angle at reference cylinder, in °;
α_t — transverse pressure angle at reference cylinder, in °;
β — helix angle at reference cylinder, in °;
β_b — helix angle at base cylinder, in °;
ε_a — transverse contact ratio;
ε_β — overlap ratio;
ε_γ — total contact ratio;
$\rho_{ao1,2}$ — tip radius of tool of pinion, wheel, in mm;
$\rho_{F1,2}$ — root fillet radius at the 30° tangent point, in mm;
R_m — tensile strength, in N/mm²;
R_{eH} — yield point, in N/mm²;
$\delta_{1,2}$ — reference cone angle of pinion, wheel, in °;
$\delta_{a1,2}$ — tip angle of pinion, wheel, in °;
Σ — shaft angle, in °;
β_m — mean spiral angle, in °;
S — cone distance, in mm;
S_m — middle cone distance, in mm;
S_e — outer cone distance, in mm.

In calculation, pinion and wheel are indicated respectively by subscript 1 and subscript 2.

1.3 Definitions①

1.3.1 For the purpose of this Appendix:

(1) For internal gears, z_2, a, d_{a2}, d_2, d_{b2}, d_{w2} are negative.

(2) The pinion is defined as the gear with the less teeth, therefore:

$$|u| = \frac{|z_2|}{z_1} \geq 1$$

where: for external gears, u is positive; for internal gears, u is negative.

(3) In the equation of surface durability, b is the common face width on the pitch diameter.

(4) In the equation of tooth root bending stress, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 and b_2 are not to be taken as greater than b by more than one module m_n on either side.

(5) The common face width b may be used also in the equation of teeth root bending stress if significant crowning or end relief has been adopted.

(6) Geometry equations concerned are as follows:

$$\tan\alpha_t = \tan\alpha_n / \cos\beta$$

$$\tan\beta_b = \tan\beta\cos\alpha_t$$

$$d_{1,2} = z_{1,2}m_n / \cos\beta$$

$$d_{b1,2} = d_{1,2}\cos\alpha_t$$

$$d_{W1} = \frac{2a}{u+1}$$

$$d_{W2} = \frac{2au}{u+1}$$

$$a = 0.5(d_{w1} + d_{w2})$$

$$z_{n1,2} = z_{1,2} / (\cos^2\beta_b \cdot \cos\beta)$$

$$m_t = m_n / \cos\beta$$

$$inv\alpha = \tan\alpha - \pi\alpha / 180\,, \quad \alpha(°)$$

---

① The following definitions are mainly based on the ISO 6336 standard for the calculation of load capacity of spur and helical gears.

$$inv\alpha_{tw}=inv\alpha_t+2\tan\alpha_n(x_1+x_2)/(z_1+z_2) \quad \text{or} \quad \cos\alpha_{tw}=\frac{m_t(z_1+z_2)}{2a}\cos\alpha_t$$

$$a_{tw}=\arccos\left(\frac{d_{b1}+d_{b2}}{2a}\right), \quad \alpha_{tw}(^\circ)$$

$$x_{hm1}+x_{hm2}=\frac{(z_1+z_2)\cdot(inv\alpha_{tw}-inv\alpha_t)}{2\tan\alpha_n}$$

$$x_{hm1,2}=\frac{h_{ao}}{m_n}-\frac{d_{1,2}-d_{f1,2}}{2m_n}$$

$$\varepsilon_\alpha=\frac{0.5\sqrt{d_{a1}^2-d_{b1}^2}\pm0.5\sqrt{d_{a2}^2-d_{b2}^2}-a\sin a_{tw}}{\pi\cdot m_t\cdot\cos\alpha_t}$$

where the positive sign is used for external gears, the negative sign for internal gears.

$$\varepsilon_\beta=\frac{b\cdot\sin\beta}{\pi m_n}$$

where for double helix, b is to be taken as the width of one helix.

$$\varepsilon_r=\varepsilon_a+\varepsilon_\beta$$

$$v=\frac{\pi\cdot d_{1,2}n_{1,2}}{60\cdot10^3}$$

$$P_{bt}=\pi m_n\cos\alpha_t/\cos\beta$$

1.3.2 Equations for bevel gears

1.3.2.1 The calculation of bevel gear strength is technically based on the equivalent cylindrical gear at the bevel gear midsection. The calculation of geometric parameters of the equivalent cylindrical gear is shown in 1.3.2.3 of this Appendix.

1.3.2.2 Index *m* refers to the midsection of bevel gear; index *v* refers to the virtual (equivalent) cylindrical gear.

1.3.2.3 The geometric parameters of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_v:

$$z_{v1,2}=\frac{z_{1,2}}{\cos\delta_{1,2}}$$

For $\Sigma = 90°$:

$$z_{v1}=z_1\frac{\sqrt{u^2+1}}{u}$$

$$z_{v2}=z_2\sqrt{u^2+1}$$

(2) Gear ratio u_v:

$$u_v=u\frac{\cos\delta_1}{\cos\delta_2}=\frac{z_{v2}}{z_{v1}}$$

For $\Sigma = 90°$:

$$u_v=(\frac{z_2}{z_1})^2=u^2$$

(3) Reference diameter d_v:

$$d_{v1,2}=\frac{d_{m1,2}}{\cos\delta_{1,2}}=\frac{d_{e1,2}}{\cos\delta_{1,2}}\frac{S_m}{S_e}$$

For $\Sigma = 90°$:

$$d_{v1}=d_{m1}\frac{\sqrt{u^2+1}}{u}$$

$$d_{v2}=u^2d_{v1}$$

(4) Centre distance a_v:

$$a_v=\frac{d_{v1}+d_{v2}}{2}$$

(5) Tip diameter d_{va}:

$$d_{va1,2} = d_{v1,2} + 2h_{am1,2}$$

(6) Base diameter d_{vb}:

$$d_{vb1,2} = d_{v1,2} \times \cos\alpha_{vt}$$

$$\alpha_{vt} = \arctan(\frac{\tan\alpha_n}{\cos\beta_m})$$

(7) Helix angle at base cylinder β_{vb}:

$$\beta_{vb} = \arcsin(\sin\ \beta_m \cos a_n)$$

(8) Transverse contact ratio ε_{va}:

$$\varepsilon_{va} = \frac{g_{va}\cos\beta_m}{m_{mn}\pi\cos a_{vt}}$$

$$g_{va} = \frac{1}{2}\left[\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}\right] - a_v \sin a_{vt}$$

(9) Overlap ratio $\varepsilon_{v\beta}$:

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{m_{mn}\pi}$$

(10) Modified contact ratio $\varepsilon_{v\gamma}$:

$$\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2}$$

(11) Mean addendum h_{am}:

$$h_{am1,2} = m_{mn} \times (1 + x_{hm1,2})$$

1.3.2.4 The geometric parameters of the normal section of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_{vn}:

$$z_{vn1} = \frac{z_{v1}}{\cos^2\beta_{vb}\cos\beta_m}$$

$$z_{vn2} = u_v z_{vn1}$$

(2) Reference diameter d_{vn}:

$$d_{vn1} = \frac{d_{v1}}{\cos^2\beta_{vb}} = z_{vn1}m_{mn}$$

$$d_{vn2} = u_v d_{vn1} = z_{vn2}m_{mn}$$

(3) Centre distance a_{vn}:

$$a_{vn} = \frac{d_{vn1} + d_{vn2}}{2}$$

(4) Tip diameter d_{van}:

$$d_{van1,2} = d_{vn1,2} + d_{va1,2} - d_{v1,2} = d_{vn1,2} + 2h_{am1,2}$$

(5) Base diameter d_{vbn}:

$$d_{vbn1,2} = d_{vn1,2}\cos a_n = z_{vn1,2}m_{mn}\cos a_n$$

(6) Contact ratio ε_{van}:

$$\varepsilon_{van} = \frac{\varepsilon_{v\alpha}}{\cos^2\beta_{vb}}$$

1.4 Nominal tangential loads F_t, F_{mt}

1.4.1 The nominal tangential loads, F_t, F_{mt}, tangential to the reference cylinder and perpendicular to the relevant axial plane, are calculated directly from the maximum continuous power or nominal power transmitted by the gear set by means of the following equations:

$$T_{1,2} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{1,2}}$$

Cylindrical gears:

$$F_t = \frac{2000 T_{1,2}}{d_{1,2}} = \frac{19.1 P \times 10^6}{n_{1,2} d_{1,2}}$$

Bevel gears:

$$F_{mt} = \frac{2000 T_{1,2}}{d_{m1,2}} = \frac{19.1 P \times 10^6}{n_{1,2} d_{m1,2}}$$

$$V_{mt} = \frac{d_{m1,2} n_{1,2}}{19098}$$

1.5 Relevant factors

1.5.1 Application factor K_A

1.5.1.1 The application factor K_A accounts for dynamic overloads from sources external to gearing. K_A, for gears designed for infinite life, is defined as the ratio between the maximum repetitive cyclic torque applied to the gear and the nominal rated torque. The nominal rated torque is defined by the rated power and speed and is the torque used in the rating calculations.

1.5.1.2 Factor K_A mainly depends on:

(1) characteristics of driving and driven machines;

(2) ratio of masses;

(3) type of couplings;

(4) operating conditions (overspeeds, changes in propeller load conditions, ...).

1.5.1.3 When operating near a critical speed of the drive system, a careful analysis of conditions must be made. The application factor K_A is to be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values in Table 1.5.1.3 may be considered.

Application factor K_A *Table 1.5.1.3*

Equipment type		K_A
Main propulsion diesel engines	With hydraulic coupling or equivalent parts	1.00
	With high elasticity coupling (general angle of torsion more than 6°)	1.30
	With elasticity coupling (general angle of torsion 2° to 6°)	1.40
	With other couplings	1.50
Main propulsion motors	Electric drive	1.00
Auxiliary gears	Electric motor and diesel engine, with hydraulic coupling or equivalent parts	1.00
	Diesel engine with high elasticity coupling (general angle of torsion more than 6°)	1.20
	Diesel engine with elasticity coupling (general angle of torsion 2° to 6°)	1.30
	Diesel engine, with other couplings	1.40

1.5.1.4 Where the ship using reduction gearing for main propulsion has an ice or PC N class notation, the nominal tangential force or the application factor is to be calculated according to the torque transmitted by reduction gearing in association with the ice or PC N class notation. See the relevant requirements in Chapter 14 of this PART or Chapter 13 of PART EIGHT of the Rules.

1.5.2 Load sharing factor K_γ

1.5.2.1 The load sharing factor K_γ accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.).

1.5.2.2 K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

1.5.2.3 The load sharing factor K_γ is to be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values may be considered for epicyclic gears:

up to 3 planetary gears: K_γ =1.00;

4 planetary gears: K_γ =1.20;

5 planetary gears: K_γ =1.30;

6 planetary gears and over: K_γ =1.40;

other gear arrangements: K_γ = 1.00;

Bevels: K_γ = 1.00.

1.5.3 Internal dynamic factor K_V

1.5.3.1 The internal dynamic factor K_V accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other. K_V is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t \cdot K_A \cdot K_\gamma$).

1.5.3.2 The factor K_V mainly depends on:

(1) transmission errors (depending on pitch and profile errors);

(2) masses of pinion and wheel;

(3) gear mesh stiffness variation as the gear teeth pass through the meshing cycle;

(4) transmitted load including application factor;

(5) pitch line velocity;

(6) dynamic unbalance of gears and shaft;
(7) shaft and bearing stiffness;
(8) damping characteristics of the gear system.

1.5.3.3 Where all the following conditions are satisfied, the internal dynamic factor K_V is to be calculated as follows:

(1) running velocity in the subcritical range, i.e.:

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 \quad \text{m/s}$$

(2) spur gears ($\beta = 0°$) and helical gears with $\beta \leq 30°$;
(3) pinion with relatively low number of teeth, $z_1 < 50$;
(4) solid disc wheels or heavy steel gear rim.

This method may be applied to all types of gears if $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3$ m/s, as well as to helical gears where $\beta > 30°$.

For gears other than the above, reference is to be made to Method B outlined in the reference standard ISO 6336-1.

(1) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$:

$$K_V = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2 \right) \times \frac{V \times Z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$$

If $K_A F_t/b$ is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.
Numerical values for the factor K_1 are to be as specified in Table 1.5.3.3.

Values of K_1 *Table 1.5.3.3*

Accuracy grades①						
Gear type	3	4	5	6	7	8
spur gears	2.1	3.9	7.5	14.9	26.8	39.1
helical gears	1.9	3.5	6.7	13.3	23.9	34.8

① The accuracy grades are to be according to ISO 1328-1:2013. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy is to be used.

For all accuracy grades, the factor K_2 is to be in accordance with the following: for
spur gears, K_2=0.0193;
for helical gears, K_2=0.0087.
Factor K is to be in accordance with the following:

If $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} \leqslant 0.2$, then $K_3 = 2.0$;

If $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} > 0.2$, then $K_3 = 2.071 - 0.357\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}}$

(2) For helical gears with overlap ratio $\varepsilon_\beta < 1$, the value K_V is determined by linear interpolation between values determined for spur gears ($K_{V\alpha}$) and helical gears ($K_{V\beta}$) in accordance with:

$$K_V = K_{V\alpha} - \varepsilon_\beta (K_{V\alpha} - K_{V\beta})$$

where: $K_{v\alpha}$ is the K_v value for spur gears, in accordance with 1.5.3.3(1);
$K_{v\beta}$ is the K_v value for helical gears, in accordance with 1.5.3.3(1).

1.5.3.4 K_V of bevel gears is to be calculated according to 1.5.3.3, with z_1, V, F_t therein being substituted by Z_{v1}, V_{mt}, F_{mt} respectively.

1.5.4 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

1.5.4.1 The face load distribution factors, K_{Hh} for contact stress and K_{Fo} for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

$K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum load per unit facewidth}}{\text{mean load per unit facewidth}}$$

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = \frac{\text{maximum bending stress at tooth root per unit facewidth}}{\text{mean bending stress at tooth root per unit facewidth}}$$

1.5.4.2 The factors $K_{H\beta}$ and $K_{F\beta}$ mainly depend on:

(1) gear tooth manufacturing accuracy;

(2) errors in mounting due to bore errors;

(3) bearing clearances;

(4) wheel and pinion shaft alignment errors;

(5) elastic deflection of gear elements, shafts, bearings, housing and foundations which support the gear elements;

(6) thermal expansion and distortion due to operating temperature;

(7) compensating design elements(tooth crowning, end relief, etc.).

1.5.4.3 The face load distribution factors K_{Hh} and K_{Fa} are to be determined according to the Method C outlined in the reference standard ISO 6336-1. Alternative methods acceptable to ISC may be applied.

In case the hardest contact is at the end of the face width, $K_{F\beta}$ is defined as follows:

$$K_{F\beta} = (K_{H\beta})^N$$

where: $N = \frac{(b/h)^2}{1+(b/h)+(b/h)^2}$, where (b/h) is the ratio of tooth width and tooth depth, to be taken as the minimum value of b_1/h_1 and b_2/h_2. Only one helical face width is to be taken for herringbone gear b. When $b/h < 3$ the value $b/h = 3$ is to be used.

In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning):

$K_{F\beta} = K_{H\beta}$.

1.5.4.4 Calculation of K_{Ha}, K_F for bevel gears

(1) $K_{H\beta}$ is to be calculated as follows:

For $b_e \geq 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta\text{-}be}$$

For $b_e < 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta\text{-}be}\ \frac{0.85b}{b_e}$$

where: $K_{H\beta\text{-}be}$ — assembling factor, see Table 1.5.4.4.

Assembling Factor $K_{H\beta\text{-}be}$ *Table 1.5.4.4*

Mounting conditions of pinion and wheel		
Both members straddle mounted	One member straddle mounted	Neither member straddle mounted
1.10	1.25	1.50

(2) $K_{F\beta}$ is to be calculated as follows:

$$K_{F\beta} = \frac{K_{H\beta}}{K_{F0}}$$

where: K_{F0} — curvature factor of tine length for bending strength, depending on helix angle and curvature in the direction of tine length, to be calculated as follows:

$$K_{F0} = 0.211\left(\frac{r_{c0}}{S_m}\right)^q + 0.789$$

$$q = \frac{0.279}{\lg(\sin\beta_m)}$$

where: r_{c0} — radius of tool, in mm;

S_m — middle cone distance, in mm;

β_m — helical angle at midpoint;

$K_{F0} = 1.15$, for $K_{F0} > 1.15$;

$K_{F0} = 1$, for $K_{F0} < 1$;

$K_{F0} = 1$, for straight or zero bevel gears.

1.5.5 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

1.5.5.1 The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

1.5.5.2 The factors $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on:

(1) total mesh stiffness;

(2) total tangential load, i.e. equivalent tangential load, including load produced by K_A, K_V, $K_{H\beta}$;

(3) base pitch error;

(4) tip relief;
(5) running-in allowance.

1.5.5.3 The transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ of cylindrical gears are to be determined according to Method B outlined in the reference standard ISO 6336-1.

1.5.5.4 K_{Ha} of bevel gears is to be determined as follows:

(1) Contact ratio $\varepsilon_{vr} \leq 2$ for equivalent cylindrical gear

$$K_{H\alpha} = \frac{\varepsilon_{vr}}{2}\left[0.9 + \frac{0.4c_r(f_{pt} - y_\alpha)}{F_{mtH}/b}\right]$$

$$F_{mtH} = F_{mt}K_AK_\gamma K_V K_{H\beta}$$

where: c_r — mesh stiffness, see 1.5.7 of this Appendix;

f_{pt} — pitch deviation of pinion or wheel, whichever is the greater;

y_a — running-in allowance, see 1.5.6 of this Appendix;

F_{mt} — nominal tangential load, see 1.4 of this Appendix;

For K_A, K_γ, K_V and $K_{H\beta}$, see 1.5 of this Appendix.

(2) Contact ratio $\varepsilon_{vr} > 2$ for equivalent cylindrical gear

$$K_{H\alpha} = 0.9 + \frac{0.4c_r(f_{pt} - y_\alpha)}{F_{mtH}/b}\sqrt{\frac{2(\varepsilon_{vr} - 1)}{\varepsilon_{vr}}}$$

(3) $K_{Ha} = 1$, for $K_{Ha} < 1$;

$K_{H\alpha} = \frac{\varepsilon_{vr}}{\varepsilon_{va}Z_{LS}^2}$, for $K_{H\alpha} > \frac{\varepsilon_{vr}}{\varepsilon_{va}Z_{LS}^2}$, where Z_{LS} is as given in 2.7 of this Appendix.

1.5.5.5 K_{Fa} of bevel gears is to be determined as follows:

$$K_{Fa} = K_{Ha}$$

$K_{Fa} = 1$, for $K_{Fa} < 1$;

$K_{F\alpha} = \frac{\varepsilon_{vr}}{\varepsilon_{va}Y_\varepsilon}$, for $K_{F\alpha} > \frac{\varepsilon_{vr}}{\varepsilon_{va}Y_\varepsilon}$ where Y_ε is as given in 3.6 of this Appendix.

1.5.6 Running-in allowance y_a

1.5.6.1 The running-in allowance y_a is the amount due to running-in by which the mesh alignment error is reduced from the start of the operation. In lack of direct experience, the value may be calculated according to Table 1.5.6.1.

Running-in Allowance *Table 1.5.6.1*

Gear material	Running-in allowance y_a	Limitation	
		Tangential speed at reference diameter (m/s)	Maximum running-in allowance (μm)
Quenched and tempered steels	$y_\alpha = \frac{160f_{pt}}{\sigma_{H\lim}}$	$v_{mt} \leq 5$	not limited
		$5 < v_{mt} \leq 10$	$y_a \leq 12800/\sigma_{H\lim}$
		$v_{mt} > 10$	$y_a \leq 6400/\sigma_{H\lim}$
Hardened steel and nitrided steels	$y_\alpha = 0.075f_{pt}$	Unlimited	$y_a \leq 3$
Two gears of different materials	$y_\alpha = \frac{y_{a1} + y_{a2}}{2}$	y_{a1} to be taken for pinion material; y_{a2} to be taken for wheel material	

1.5.7 Mesh stiffness c_γ

1.5.7.1 The mesh stiffness is the load to be applied on the line of contact to induce a deflection of 1 μm at 1 mm face width for one or more pairs of simultaneously meshed precision gears.

1.5.7.2 The mesh stiffness of bevel gears may be determined as follows:

$$c_\gamma = c_{\gamma 0}c_F c_b$$

where: $c_{\gamma 0}$ — mesh stiffness in the mean condition, taken as 20 N/mm·μm if no direct experience being available;

c_F and c_b — modification coefficients:

$c_F = 1$, for $F_{mt}K_A/b_e \geq 100$ N/mm;

$c_F = F_{mt}K_A/100b_e$, for $F_{mt}K_A/b_e < 100$ N/mm;

$c_b = 1$, for $b_e/b \geq 0.85$;

$c_b = b_e/0.85b$, for $b_e/b < 0.85$.

2 *Surface Durability*

2.1 Calculation requirements

2.1.1 The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The surface contact stress σ_H must be equal to or less than the permissible contact stress σ_{HP}.

2.1.2 Surface contact stress and permissible contact stress of pinion and wheel are to be calculated respectively.

2.2 Surface contact stress σ_H

2.2.1 Surface contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{HO} \sqrt{K_A K_\gamma K_V K_{H\alpha} K_{H\beta}}$$

where: σ_{HO} = basic value of contact stress for pinion and wheel:

(1) Cylindrical gears:

for pinion:

$$\sigma_{HO} = Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

for wheel:

$$\sigma_{HO} = Z_D Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

(2) Bevel gears:

$$\sigma_{HO} = Z_{M\text{-}B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{v1} l_{bm}} \times \frac{u_v+1}{u_v}} \quad \text{N/mm}^2$$

For the shaft angle $\Sigma = \delta_1 + \delta_2 = 90°$, the following applies:

$$\sigma_{HO} = Z_{M-B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{m1} l_{bm}} \times \frac{\sqrt{u_v^2+1}}{u_v}} \quad \text{N/mm}^2$$

where: Z_B — single pair tooth contact factor for pinion , see 2.3 of this Appendix;
Z_D — single pair tooth contact factor for wheel, see 2.3 of this Appendix;
$Z_{M\text{-}B}$ — mid-zone factor, see 2.3 of this Appendix;
Z_H — zone factor, see 2.4 of this Appendix;
Z_E — elasticity factor, see 2.5 of this Appendix;
Z_ε — contact ratio factor, see 2.6 of this Appendix;
Z_{LS} — load sharing factor, see 2.7 of this Appendix;
Z_K — bevel gear factor (flank), see 2.8 of this Appendix;
Z_β — helix angle factor, see 2.9 of this Appendix;
l_{bm} — length of middle line of contact, see 3.7 of this Appendix;
for K_A, K_V, $K_{H\alpha}$ and $K_{H\beta}$, see 1.5 of this Appendix.

2.2.2 Permissible contact stress σ_{HP} is to be determined as follows:

$$\sigma_{HP} = (\sigma_{H\lim} / S_H) Z_N Z_L Z_V Z_R Z_W Z_X \quad \text{N/mm}^2$$

where: $\sigma_{H\lim}$ — endurance limit for contact stress, see 2.10 of this Appendix;
Z_N — life factor for contact stress, see 2.11 of this Appendix;
Z_L, Z_V, Z_R —lubrication factor, velocity factor and roughness factor respectively, see 2.12 of this Appendix;
Z_W — hardness ratio factor, see 2.13 of this Appendix;
Z_X — size factor for contact stress, see 2.14 of this Appendix;
S_H — safety factor for contact stress, see 2.15 of this Appendix.

2.3 Single pair tooth contact factors Z_B, Z_D and mid-zone factor $Z_{M\text{-}B}$

2.3.1 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, account for the influence of the tooth flank curvature on contact stresses at the inner point of single pair contact in relation to Z_H.

The mid-zone factor $Z_{M\text{-}B}$ is used to convert the contact stress at the pitch point to the contact stress at the midpoint M of loading, see Figure 2.3.1.

2.3.2 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, are to be determined as follows:

2.3.2.1 For spur gears, $\varepsilon_\beta = 0$

(1) $Z_B = M_1$ or 1, whichever is greater:

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\frac{2\pi}{z_1})\right]\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_2})\right]}}$$

(2) $Z_D = M_2$ or 1, whichever is greater:

$$M_2 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\frac{2\pi}{z_2})\right]\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_1})\right]}}$$

2.3.2.2 For helical gears,

(1) if $\varepsilon_\beta \geq 1$, $Z_B = Z_D = 1$;

(2) if $\varepsilon_\beta < 1$, to be calculated by interpolation:

$Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$, and $Z_B \geq 1$;

$Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$, and $Z_D \geq 1$.

2.3.2.3 For internal gears, $Z_D = 1$.

2.3.3 Mid-zone factor $Z_{M\text{-}B}$

The factor $Z_{M\text{-}B}$ may be calculated as follows:

$$Z_{M\text{-}B} = \frac{\tan \alpha_{vt}}{\sqrt{\left[\sqrt{(\frac{d_{va1}}{d_{vb1}})^2 - 1} - F_1 \frac{\pi}{z_{v1}}\right]\left[\sqrt{(\frac{d_{va2}}{d_{vb2}})^2 - 1} - F_2 \frac{\pi}{z_{v2}}\right]}}$$

where: F_1, F_2 — auxiliary factors, see Table 2.3.3.

Auxiliary Factors for Determination of Mid-Zone Factor *Table 2.3.3*

Overlap ratio of equivalent cylindrical gear	F_1	F_2
$\varepsilon_{v\beta} = 0$	2	$2(\varepsilon_{v\alpha} - 1)$
$0 < \varepsilon_{v\beta} \leq 1$	$2 + (\varepsilon_{v\alpha} - 2)\varepsilon_{v\beta}$	$2\varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha})\varepsilon_{v\beta}$
$\varepsilon_{v\beta} > 1$	$\varepsilon_{v\alpha}$	$\varepsilon_{v\alpha}$

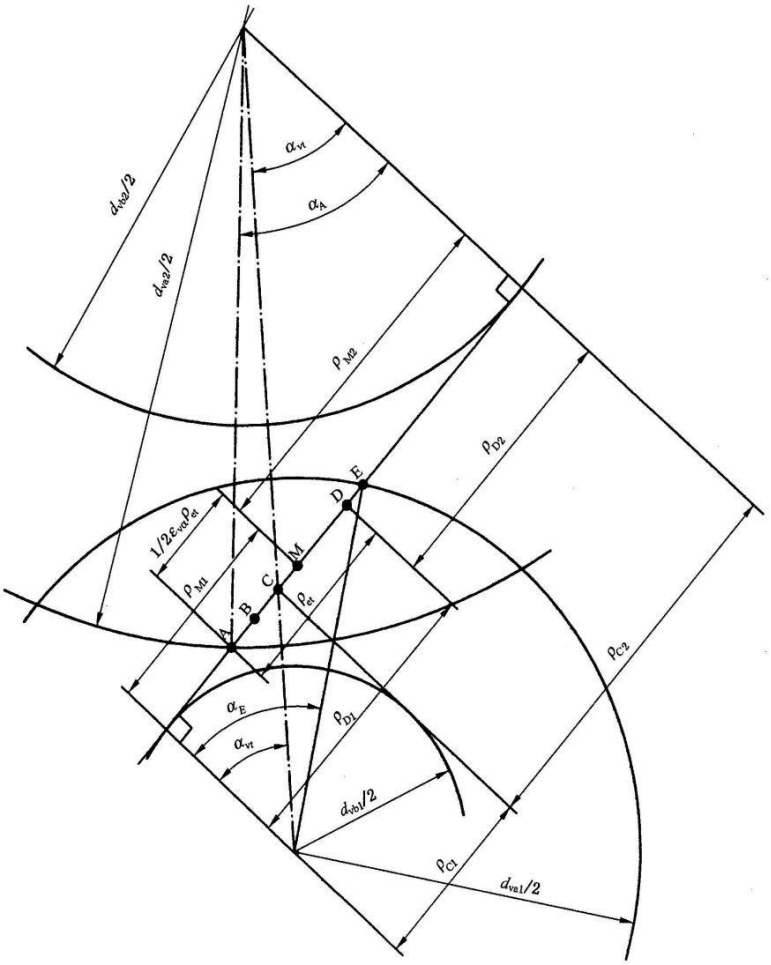


Figure 2.3.1 Radius of Curvature at Midpoint M and Single-Pair Mesh Point B of the Pinion, for Determination of Mid-Zone Factor

2.4 Zone factor Z_H

2.4.1 The zone factor, Z_H, accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal load at the pitch cylinder.

2.4.2 The zone factor Z_H is to be calculated as follows:

(1) For cylindrical gears:

$$Z_H = \sqrt{\frac{2\cos\beta_b}{\cos^2\alpha_t \tan\alpha_{tw}}}$$

(2) For bevel gears:

$$Z_H = 2\sqrt{\frac{\cos\beta_{vb}}{\sin(2\alpha_{vt})}}$$

Some normal common pressure angles of bevel gears may be obtained from Figure 2.4.2.

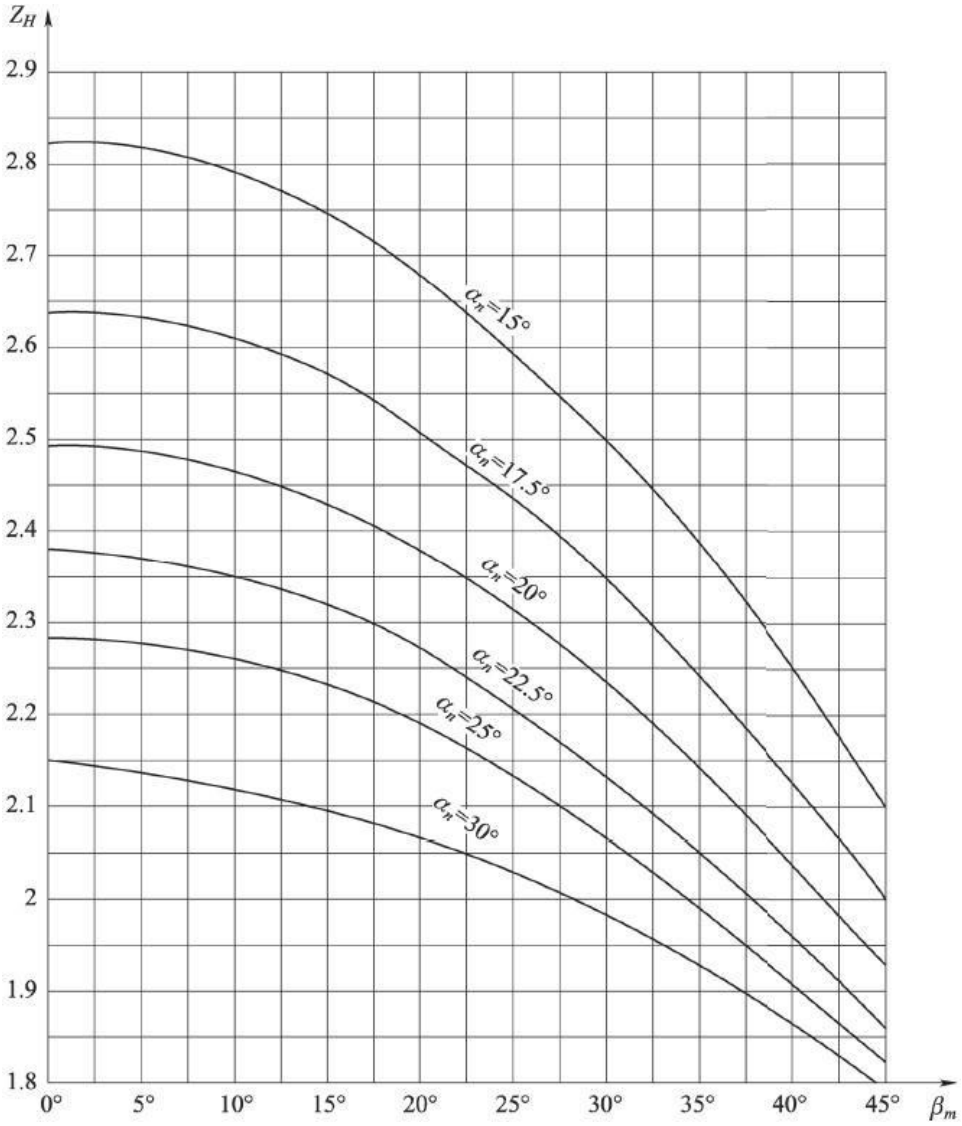


Figure 2.4.2 Zone Factor Z_H for X-Zero Bevel Gears

2.5 Elasticity factor Z_E

2.5.1 The elasticity factor, Z_E, accounts for the influence of the material properties E (modulus of elasticity) and v (Poisson's ratio) on the contact stress.

2.5.2 The factor Z_E is to be calculated as follows:

$$Z_E = \sqrt{\frac{1}{\pi\left(\frac{1-v_1^2}{E_1} + \frac{1-v_2^2}{E_2}\right)}}$$

For $E_1 = E_2 = E$ and $v_1 = v_2 = v$:

$$Z_E = \sqrt{\frac{E}{2\pi(1-v^2)}}$$

For $v = 0.3$ in respect to steel and hard aluminum alloys:

$$Z_E = \sqrt{0.175\,E}$$

Where the modulus of elasticity of the material of a pair is E_1 or E_2, the following applies:

$$E = \frac{2E_1E_2}{E_1 + E_2}$$

For steel gears (E = 206000 N/mm^2, v = 0.3):

$$Z_E = 189.8\ \sqrt{\text{N/mm}^2}$$

2.5.3 In other cases, reference is to be made to ISO 6336-2 standard.

2.6 Contact ratio factor Z_ε

2.6.1 The contact ratio factor, Z_ε, accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

2.6.2 The contact ratio factor Z_ε is to be calculated as follows:

Spur gears: $$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$$

Helical gears: $$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta)+\frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

2.7 Bevel gear load sharing factor Z_{LS}

2.7.1 The load sharing factor, Z_{LS}, accounts for the load sharing between two or more pairs of teeth in contact.

2.7.2 The load sharing factor, Z_{LS}, may be calculated as follows:

(1) $Z_{LS} = 1$ for $\varepsilon_{vr} \leq 2$ or $\varepsilon_{v\beta} < 1$.

(2) For $\varepsilon_{vr} > 2$ and $\varepsilon_{v\beta} > 1$, Z_{LS} is to be calculated as follows:

$$Z_{LS} = \left\{1+2\left[1-\left(\frac{2}{\varepsilon_{vr}}\right)^{1.5}\right]\sqrt{1-\frac{4}{\varepsilon_{vr}^2}}\right\}^{-0.5}$$

2.7.3 Where Z_{LS} obtained according to 2.7.2(2) is less than 0.837, Z_{LS} is to be taken as 0.837.

2.8 Bevel gear factor Z_K

2.8.1 The bevel gear factor Z_K is an empirical factor and accounts for the difference between bevel and cylindrical loading and adjusts the contact stresses so that the same permissible stresses may apply.

2.8.2 $Z_K = 0.8$ may be taken in lack of detailed data.

2.9 Helix angle factor Z_β

2.9.1 The helix angle factor, Z_β, accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact.

2.9.2 Z_β is to be calculated as follows:

(1) Cylindrical gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

(2) Bevel gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta_m}}$$

2.10 Endurance limit for contact stress σ_{Hlim}

2.10.1 For a given material, σ_{Hlim} is the limit of repeated contact stress which can be permanently endured.

2.10.2 The value of σ_{Hlim} may be regarded as the level of contact stress which the material will endure without pitting for at least 5×10^7 load cycles. For this purpose, pitting is defined by:

(1) for not surface hardened gears: pitted area > 2% of total active flank area;

(2) for surface hardened gears: pitted area > 0.5% of total active flank area, or > 4% of one particular tooth flank area.

2.10.3 The σ_{Hlim} values are to correspond to a failure probability of 1% or less.

2.10.4 The endurance limit mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

2.10.5 The endurance limit for contact stress σ_{Hlim} is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

2.11 Life factor Z_N

2.11.1 The life factor Z_N accounts for the higher permissible contact stress in case a limited life (number of cycles) is required.

2.11.2 The factor Z_N mainly depends on:

(1) material and heat treatment;
(2) number N_L of load cycles (service life);
(3) lubrication;
(4) failure criterion;
(5) required operational smoothness;
(6) pitch line velocity;
(7) cleanliness of material;
(8) plasticity and fracture toughness of material;
(9) residual stresses;
(10) influence factors (Z_R, Z_V, Z_L, Z_W, Z_X).

2.11.3 The life factor Z_N is to be determined according to Method B outlined in the reference standard ISO 6336-2.

2.12 Influence factors of lubrication film on contact stress, Z_L, Z_V and Z_R

2.12.1 The lubricant factor, Z_L, accounts for the influence of the type of lubricant and its viscosity. The velocity factor, Z_V, accounts for the influence of the pitch line velocity. The roughness factor, Z_R, accounts for the influence of the surface roughness on the surface endurance capacity. The factors may be determined for the softer material where gear pairs are of different hardness.

2.12.2 The factors mainly depend on:

(1) viscosity of lubricant in the contact zone;
(2) the sum of the instantaneous velocities of the tooth surfaces;
(3) load;
(4) relative radius of curvature at the pitch point;
(5) surface roughness of teeth flanks;
(6) hardness of pinion and gear.

2.12.3 The lubricant factor Z_L is to be calculated as follows:

$$Z_L = C_{ZL} + \frac{4(1.0 - C_{ZL})}{(1.2 + 134/\nu_{40})^2}$$

where: C_{ZL} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1,200 N/mm²,

$$C_{ZL} = 0.83 + 0.08\frac{\sigma_{H_{lim}} - 850}{350}$$

if σ_{Hlim} < 850 N/mm², take C_{ZL} = 0.83;
if σ_{Hlim} >1,200 N/mm², take C_{ZL} = 0.91;

ν_{40} — nominal kinematic viscosity of the oil at 40℃.

2.12.4 The velocity factor Z_V is to be calculated as follows:

$$Z_V = C_{ZV} + \frac{2(1.0 - C_{ZV})}{\sqrt{0.8 + 32/V}}$$

where: C_{ZV} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1200 N/mm²,

$$C_{ZV} = C_{ZL} + 0.02$$

if σ_{Hlim} <850 N/mm², take C_{ZV} = 0.85;
if σ_{Hlim} >1,200 N/mm², take C_{ZV} = 0.93.

2.12.5 The roughness factor Z_R is to be calculated as follows:

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where: R_{Z10} — relative mean roughness (curvature radius relative to pitch point ρ_{red} = 10 mm):

$$R_{Z10} = \frac{R_{Z1} + R_{Z2}}{2} \sqrt[3]{\frac{10}{\rho_{red}}}$$

R_{Z1} and R_{Z2} —mean peak-to-valley roughness determined respectively for the pinion and the wheel (refer to ISO 6336-2 standard);

ρ_{red} — relative radius of curvature, to be determined from the following equation:

(1) for cylindrical gears:

$$\rho_{red} = \frac{\rho_1 \rho_2}{\rho_1 + \rho_2}$$

(2) for bevel gears:

$$\rho_{red} = \frac{\rho_{v1} \rho_{v2}}{\rho_{v1} + \rho_{v2}}$$

where: $\rho_{1,2} = 0.5 \times d_{b1,2} \times \tan\alpha_{tw}$;

$\rho_{v1,2} = 0.5 \times d_{vb1,2} \times \tan\alpha_{tw}$.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_z/6$$

C_{ZR} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1,200 N/mm², C_{ZR} = 0.32 – 0.0002σ_{Hlim};

if σ_{Hlim} < 850 N/mm², take C_{ZR} =0.15;

if σ_{Hlim} > 1,200 N/mm², take C_{ZR} =0.08.

2.13 Hardness ratio factor Z_W

2.13.1 The hardness ratio factor, Z_W, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear (mean peak-to-valley roughness $R_Z \leq 6$ μm or rough arithmetic mean value $R_a \leq 1$ μm) with a smooth surface in the following cases.

If $HB < 130$, $Z_W = 1.2 \times (\frac{3}{R_{zH}})^{0.15}$;

If $130 \leq HB \leq 470$, $Z_W = (1.2 - \frac{HB - 130}{1700}) \times (\frac{3}{R_{zH}})^{0.15}$;

If $HB > 470$, $Z_W = (\frac{3}{R_{zH}})^{0.15}$.

(1) Surface-hardened pinion with through-hardened wheel

where: HB = Brinell hardness of the tooth flanks of the softer gear of the pair;

R_{zH} — equivalent roughness, μm

$$R_{zH} = \frac{R_{z1} \times (\frac{10}{\rho_{red}})^{0.33} \times (\frac{R_{z1}}{R_{z2}})^{0.66}}{(v \times v_{40}/1500)^{0.33}}$$

ρ_{red}— relative radius of curvature.

(2) Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. Z_W applies to the wheel only, not to the pinion.

If $HB_1/HB_2 < 1.2$, $Z_W = 1$

If $1.2 \leq HB_1/HB_2 \leq 1.7$, $Z_W = 1 + \left(0.00898 \frac{HB_1}{HB_2} - 0.00829\right) \times (u - 1)$

If $HB_1/HB_2 > 1.7$, $Z_W = 1 + 0.00698 \cdot (u - 1)$

If gear ratio $u > 20$ then the value $u = 20$ is to be used.

In any case, if calculated $Z_W < 1$ then the value $Z_W = 1.0$ is to be used.

2.14 Size factor of contact stress, Z_X

2.14.1 The size factor, Z_X, accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

2.14.2 The factor mainly depends on:

(1) material and heat treatment;

(2) tooth and gear dimensions;
(3) ratio of case depth to tooth size;
(4) ratio of case depth to equivalent radius of curvature.

2.14.3 For through-hardened gears and for surface-hardened gears with adequate case depth relative to tooth size and radius of relative curvature, Z_x =1. When the case depth is relatively shallow, then a smaller value of Z_X is to be chosen.

2.15 Safety factor for contact stress, S_H

2.15.1 The safety factor for contact stress, S_H, can be assumed by taking into account the type of application. The safety factor for contact stress S_H is to satisfy the following guidance values:

Main propulsion gears: $1.20 \le S_H \le 1.40$;

Auxiliary gears: $1.15 \le S_H \le 1.20$.

For gearing of duplicated independent propulsion or auxiliary machinery, a reduced value can be assumed.

3 *Tooth Root Bending Strength*

3.1 Calculation requirements

3.1.1 The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress σ_F is to be equal to or less than the permissible root stress σ_{FP}.

3.1.2 The root stress σ_F and the permissible root stress σ_{FP} are to be calculated separately for the pinion and the wheel.

3.1.3 The following formulae and definitions apply to gears having rim thickness greater than 3.5 m_n.

3.1.4 The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°. For larger pressure angles and large helix angles, the calculated results are to be confirmed by experience as by ISO 6336-3 Method A and the relevant standard.

3.2 Tooth root bending stress for pinion and wheel σ_F

3.2.1 Tooth root bending stress for pinion and wheel σ_F is to be calculated as follows:

(1) For cylindrical gears:

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta Y_B Y_{DT} K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \le \sigma_{FP}$$

(2) For bevel gears:

$$\sigma_F = \frac{F_{mt}}{bm_{mn}} Y_{Fa} Y_{Sa} Y_\varepsilon Y_K Y_{LS} K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \le \sigma_{FP}$$

where: Y_F, Y_{Fa} — tooth form factor, see 3.3 of this Appendix;

Y_S, Y_{Sa} — stress correction factor, see 3.4 of this Appendix;

Y_β — helix angle factor, see 3.5 of this Appendix;

$Y\varepsilon$ — contact ratio factor, see 3.6 of this Appendix;

Y_K — bevel gear factor, see 3.7 of this Appendix;

Y_{LS} — load sharing factor, see 3.8 of this Appendix;

Y_B — rim thickness factor, see 3.15 of this Appendix;

Y_{DT} — deep tooth factor, see 3.16 of this Appendix;

for F_t, K_A, K_γ, K_V, K_{Fa} and $K_{F\beta}$, see 1.4 and 1.5 of this Appendix;

for b and m_n, see 1.2 of this Appendix.

3.2.2 Permissible tooth root bending stress for pinion and wheel, σ_{FP}, is to be calculated as follows:

$$\sigma_{FP} = \frac{\sigma_{FE} \times Y_N \times Y_d}{S_F} Y_{\delta relT} \times Y_{RrelT} \times Y_X \quad \text{N/mm}^2$$

where: σ_{FE} — bending endurance limit, see 3.9 of this Appendix;

Y_d — design factor, see 3.10 of this Appendix;

Y_N — life factor, see 3.11 of this Appendix;

$Y_{\delta relT}$ — relative notch sensitivity factor, see 3.12 of this Appendix;

Y_{RrelT} — relative surface factor, see 3.13 of this Appendix;

Y_X — size factor of bending stress, see 3.14 of this Appendix;

S_F — safety factor for tooth root bending stress, see 3.17 of this Appendix.

3.3 Tooth form factors Y_F, Y_{Fa}

3.3.1 The tooth form factors, Y_F and Y_{Fa}, represent the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact.

3.3.2 Y_F and Y_{Fa} are to be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing are to be determined in the normal section, i.e. for the virtual spur gear with virtual number of teeth z_n.

3.3.3 Tooth form factor of cylindrical gears, Y_F

For the pinion and the wheel, the tooth form factor is to be calculated as follows:

$$Y_F = \frac{6\frac{h_F}{m_n}\cos\alpha_{Fen}}{(\frac{S_{Fn}}{m_n})^2\cos\alpha_n}$$

where: h_F — bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact, in mm;

S_{Fn} — tooth root normal chord in the critical section, in mm;

α_{Fen} — pressure angle at the outer point of single tooth pair contact in the normal section, in °.

h_F, α_{Fen} and S_{Fn} are shown in Figure 3.3.3.

For the calculation of h_F, α_{Fen} and S_{Fn}, the procedure outlined in the reference standard ISO 6336-3 (Method B) is to be used.

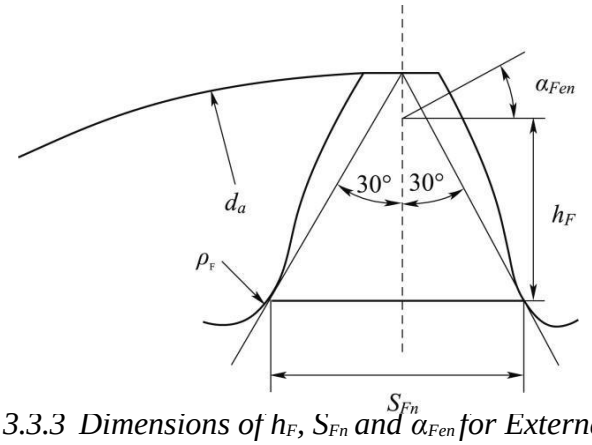


Figure 3.3.3 Dimensions of h_F, S_{Fn} and α_{Fen} for External Gear

3.3.4 Tooth form factor for bevel gears, Y_{Fa}

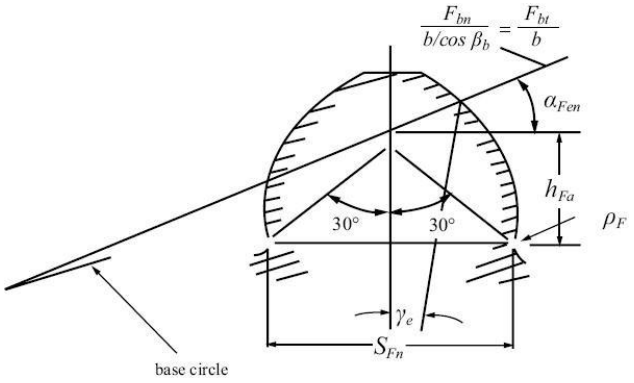
3.3.4.1 The tooth form factor Y_{Fa} represents the influence on nominal bending stress of the tooth form with load applied at the tooth tip. In calculation by this method, the section at 30° tangent point of the tooth root transition curve beyond the normal tooth profile of the equivalent cylindrical gear is the critical section.

3.3.4.2 The tooth form factor is to be determined separately for the pinion and the wheel. Depending on different manufacturing methods, specific equations are respectively given in 3.3.4.4 and 3.3.4.5, with relevant parameters being defined in Figure 3.3.4.

3.3.4.3 The tooth form factor of generated gears is also to comply with the following:

(1) the contact point of the 30° tangent lies on the fillet curve generated by cutter tip radius;

(2) the cutter must have a tip fillet radius ($\rho_{a0} \neq 0$).



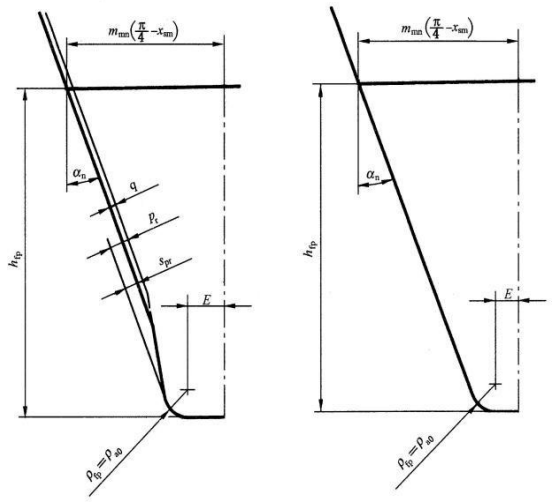


Figure 3.3.4 Factors Influencing Tooth Form of Bevel Gears

3.3.4.4 The tooth form factor of generated gears may be calculated as follows:
(1) Tooth form factor Y_{Fa}:

$$Y_{Fa}=\frac{6(\frac{h_{Fa}}{m_{mn}})\cos\alpha_{Fan}}{(\frac{S_{Fn}}{m_{mn}})^2\cos\alpha_n}$$

(2) For calculation of tooth root chord S_{Fn} in the critical section and bending moment arm h_{Fa}, the auxiliary values E, G, H and θ are first to be determined:

$$E=(\frac{\pi}{4}-x_{sm})m_{mn}-h_{ao}\tan\alpha_n-\frac{\rho_{ao}(1-\sin\alpha_n)-s_{pr}}{\cos\alpha_n}$$

$$G=\frac{\rho_{ao}}{m_{mn}}-\frac{h_{ao}}{m_{mn}}+x_{hm}$$

$$H=\frac{2}{z_{vn}}(\frac{\pi}{2}-\frac{E}{m_{mn}})-\frac{\pi}{3}$$

$$\theta=\frac{2G}{z_{vn}}\tan\theta-H$$

It is recommended to take the initial value $\theta=\pi/6$ to obtain θ by iterative method.

(3) Tooth root chord S_{Fn} in the critical section:

$$\frac{S_{Fn}}{m_{mn}}=Z_{vn}\sin(\frac{\pi}{3}-\theta)+\sqrt{3}(\frac{G}{\cos\theta}-\frac{\rho_{ao}}{m_{mn}})$$

(4) Tooth root fillet radius ρ_F in the critical section:

$$\frac{\rho_F}{m_{mn}}=\frac{\rho_{ao}}{m_{mn}}+\frac{2G^2}{\cos\theta(z_{vn}\cos^2\theta-2G)}$$

(5) Bending moment arm h_{Fa}:

$$\alpha_{an}=\arccos(d_{vbn}/d_{van})$$

$$\gamma_a=\frac{1}{z_{vn}}[\frac{\pi}{2}+2(x_{hm}\tan\alpha_n+x_{sm})]+inv\alpha_n-inv\alpha_{an}$$

$$\alpha_{Fan}=\alpha_{an}-\gamma_a$$

$$\frac{h_{Fa}}{m_{mn}}=\frac{1}{2}\left[(\cos\gamma_a-\sin\gamma_a\tan\alpha_{Fan})\frac{d_{van}}{m_{mn}}-z_{vn}\cos(\frac{\pi}{3}-\theta)-\frac{G}{\cos\theta}+\frac{\rho_{ao}}{m_{mn}}\right]$$

For gears having a basic rack profile of $\alpha_n=20°$, $h_{a0}/m_{mn}=1.25$, $\rho_{a0}/m_{mn}=0$ and $x_{sm}=0$, the tooth form factor may be obtained from Figure 3.3.4.4.

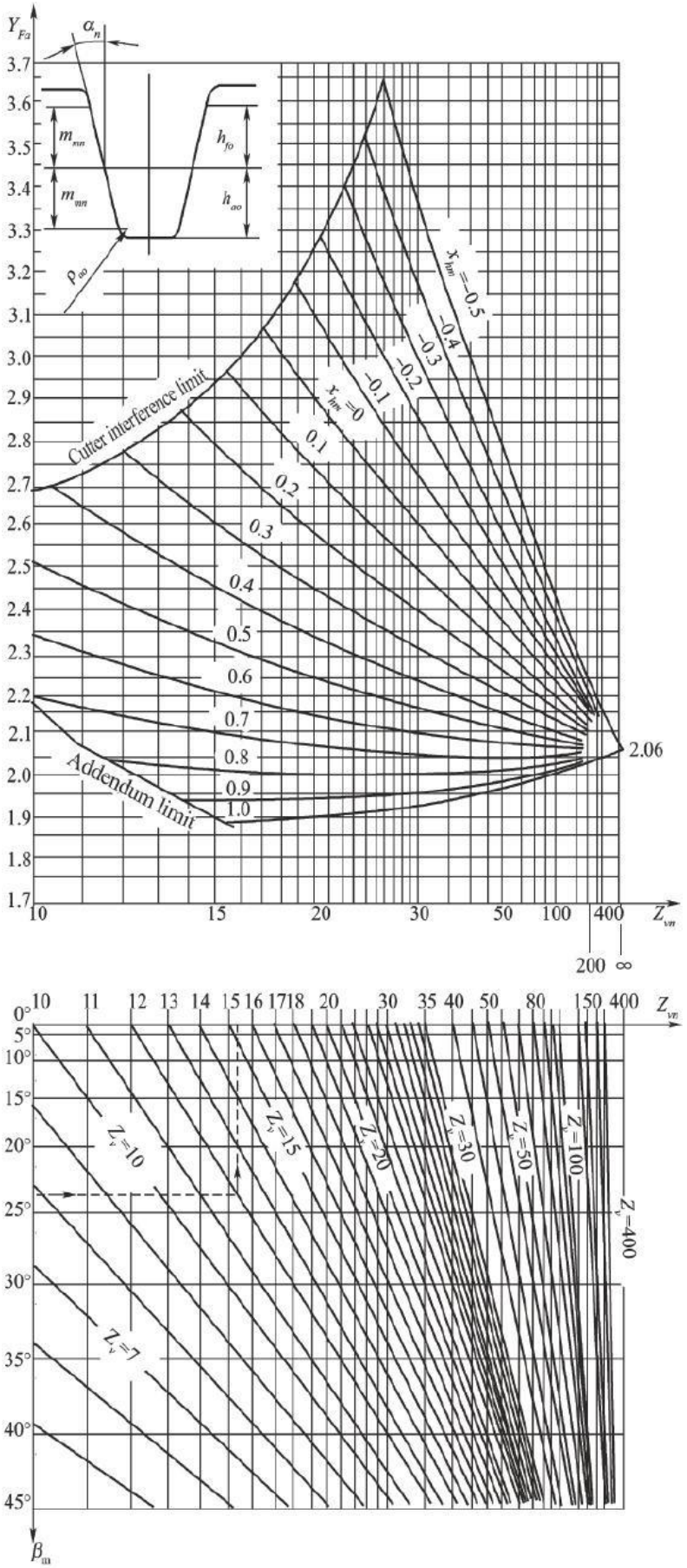


Figure 3.3.4.4 Tooth Form Factor of Generated Gears

3.3.4.5 Tooth form factor Y_{Fa} of form cutting

The tooth form factor of form cutting may be calculated as follows:

(1) Tooth root chord in the critical section

$$s_{Fn2} = \pi m_{mn} - 2E - 2\rho_{a02}\cos 30^{o}$$

where: E is to be calculated according to 3.3.4.4(2).

(2) Fillet radius at contact point of 30° tangent

$$\rho_{F2} = \rho_{a02}$$

(3) Bending moment arm

$$h_{Fa2} = h_{a02} - \frac{\rho_{a02}}{2} + m_{mn} - (\frac{\pi}{4} + x_{sx2} - \tan a_n) m_{mn} \tan a_n$$

(4) The tooth form factor is to be calculated as follows:

$$Y_{Fa} = \frac{6\frac{h_{Fa2}}{m_{mn}}}{(\frac{S_{Fn2}}{m_{mn}})^2}$$

3.4 Stress correction factors Y_S, Y_{Sa}

3.4.1 The stress correction factors are used to convert the nominal bending stress to the local tooth root stress, taking into account the effects of stress concentration at the tooth root transition curve and stresses other than bending stresses on the root stress.

3.4.2 The factors apply to the load application at the outer point of single tooth pair contact and are to be determined separately for the pinion and for the wheel.

3.4.3 Y_S value is to be determined with the following equation (having range of validity: $1 \le q_s < 8$):

(1) Stress correction factor Y_S of cylindrical gears:

$$Y_S = (1.2 + 0.13L) q_s^{(\frac{1}{1.21+2.3/L})}$$

(2) Stress correction factor Y_{Sa} of bevel gears:

$$Y_{Sa} = (1.2 + 0.13L_a) q_s^{(\frac{1}{1.21+2.3/L_a})}$$

where : q_s — notch parameter, $q_s = \frac{S_{Fn}}{2\rho_F}$

$$L = \frac{S_{Fn}}{h_F}$$

$$L_a = \frac{S_{Fn}}{h_{Fa}}$$

ρ_F = root fillet radius in the critical section, mm. For the calculation of ρ_F the procedure outlined in the reference standard ISO 6336-3 is to be used.

For bevel gears having the basic rack profile of the tooth with $\alpha_n = 20^{o}, h_{a0}/m_{mn} = 1.25, \rho_{a0}/m_{mn} = 0$ and x_{sm}= 0, the stress correction factors may be obtained from Figure 3.4.3.

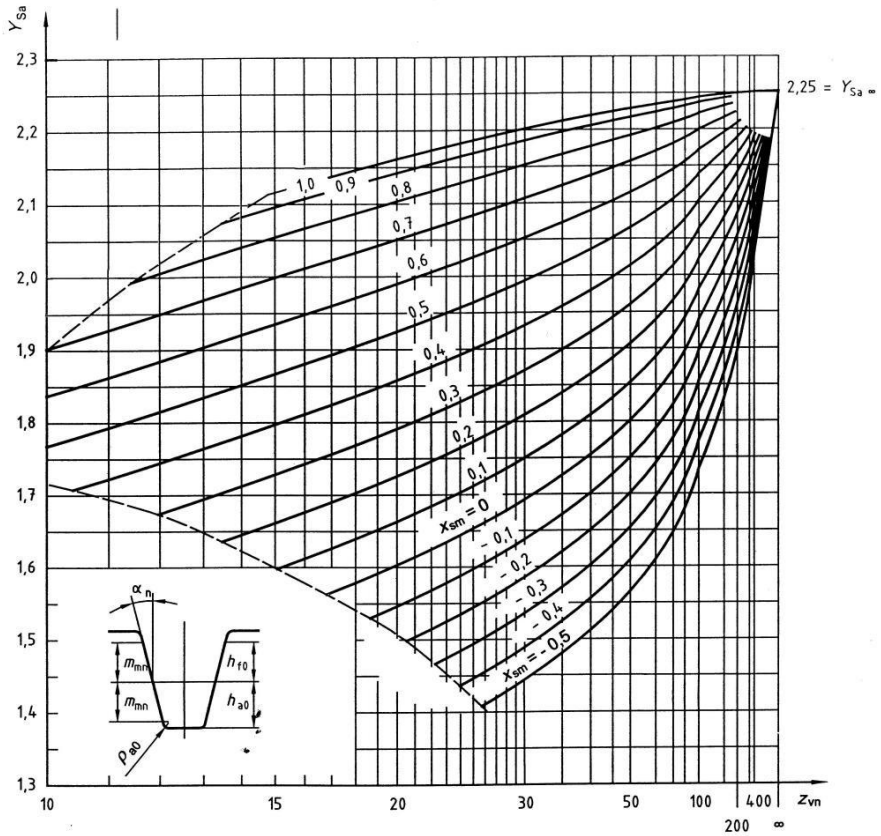


Figure 3.4.3 Stress Correction Factors for Tooth Form Factor of Generated Gear with Load Applied at Tooth Tip

3.5 Helix angle factor Y_β

3.5.1 The helix angle factor, Y_β, covers the effects of an oblique line of contact caused by the helix angle of cylindrical gears on the root stress.

3.5.2 The helix angle factor, Y_β is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where: β — reference helix angle in degrees, 30° is substituted for β > 30°;
ε_β — overlap ratio, the value 1.0 is substituted for ε_β when ε_β > 1.0.

3.6 Contact ratio factor Y_ε

3.6.1 The contact ratio factor Y_ε covers the effects of an oblique line of contact caused by the helix angle of bevel gears on the root stress.

3.6.2 The contact ratio factor Y_ε may be calculated as follows:

(1) For $\varepsilon_{v\beta} = 0$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}}$$

(2) For $0 < \varepsilon_{v\beta} \leq 1$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}} - \varepsilon_{v\beta}\left(\frac{0.75}{\varepsilon_{va}} - 0.375\right)$$

For $\varepsilon_{v\beta} > 1$:

$$Y_\varepsilon = 0.625$$

3.6.3 Where Y_ε calculated according to 3.6.2 is less than 0.625, Y_ε is to be taken as 0.625.

3.7 Bevel gear factor Y_K

3.7.1 The bevel gear factor Y_K accounts for the differences between bevel and cylindrical gears in respect to root stress.

3.7.2 The bevel gear factor Y_K may be calculated as follows:

$$Y_K = (\frac{1}{2} + \frac{l'_{bm}}{2b})^2 \frac{b}{l'_{bm}}$$

$$l'_{bm} = l_{bm} \cos \beta_{vb}$$

where: l'_{bm} — projected length of the middle line of contact;

l_{bm} — length of the middle line of contact:

For $\varepsilon_{v\beta} < 1$: $l_{bm} = \frac{b\varepsilon_{va}}{\cos \beta_{vb}} \frac{\sqrt{\varepsilon_{vr}^2 - [(2 - \varepsilon_{va})(1 - \varepsilon_{v\beta})]^2}}{\varepsilon_{vr}^2}$;

For $\varepsilon_{v\beta} \geq 1$: $l_{bm} = \frac{b\varepsilon_{va}}{\cos \beta_{vb} \varepsilon_{vr}}$.

3.8 Load sharing factor Y_{LS}

3.8.1 The load sharing factor, Y_{LS}, accounts for the distribution of load between two or more pairs of teeth.

3.8.2 The factor Y_{LS} may be calculated as follows:

$$Y_{LS} = Z_{LS}^2$$

where: Z_{LS} — load sharing factor, see 2.7 of this Appendix.

3.8.3 Where Z_{LS} calculated according to 3.8.2 is less than 0.7, Z_{LS} is to be taken as 0.7.

3.9 Bending endurance limit σ_{FE}

3.9.1 For a given material, bending endurance limit σ_{FE} is the local tooth root stress which can be permanently endured. According to the reference standard the number of 3×10^6 cycles is regarded as the beginning of the endurance limit. The σ_{FE} values are to correspond to a failure probability 1% or less.

σ_{FE} is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as alternating stress or prestressing etc., are covered by the design factor Y_d.

3.9.2 The endurance limit σ_{FE} mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

3.9.3 The bending endurance limit σ_{FE} is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

3.10 Design factor Y_d

3.10.1 The design factor, Y_d, takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength, relative to the tooth root strength with unidirectional load as defined for σ_{FE}.

3.10.2 The design factor, Y_d, is to be determined as follows:

(1) for gears with unidirectional load: $Y_d = 1.0$;

(2) for gears with occasional part load in reversed direction, such as idler gear and planet wheel: $Y_d = 0.7$;

(3) for gears with performance in reversing: $Y_d = 0.9$;

(4) for gears shrinking on assembled gear rings: $Y_d = 0.8$.

3.11 Life factor Y_N

3.11.1 The life factor Y_N accounts for the higher tooth root bending stress permissible when a limited life (number of cycles) is required.

3.11.2 The factor Y_N mainly depends on:

(1) material and heat treatment;

(2) number of load cycles (service life);

(3) influence factors ($Y_{\delta relT}$, Y_{RrelT}, Y_X).

3.11.3 The life factor Y_N may also be determined according to Method B outlined in the reference standard ISO 6336-3.

3.12 Relative notch sensitivity factor $Y_{\delta relT}$

3.12.1 The relative notch sensitivity factor, $Y_{\delta relT}$, indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

3.12.2 The factor $Y_{\delta relT}$ mainly depends on:

(1) material;

(2) relative stress gradient.

3.12.3 $Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT}=\frac{1+\sqrt{0.2\rho'(1+2q_s)}}{1+\sqrt{1.2\rho'}}$$

where: q_s = notch parameter, see 3.4 of this Appendix;

ρ' = slip-layer thickness, mm, from Table 3.12.3.

Value of Slip-layer Thickness ρ' *Table 3.12.3*

Material		ρ'(mm)
Case hardened steels, flame or induction hardened steels		0.0030
Through-hardened steels①, yield point R_e	500 N/mm^2	0.0281
	600 N/mm^2	0.0194
	800 N/mm^2	0.0064
	1000 N/mm^2	0.0014
Nitrided steels		0.1005

Note: ① The given values of ρ' can be interpolated for values of R_e not stated above.

3.13 Relative surface factor Y_{RrelT}

3.13.1 The relative surface factor, Y_{RrelT}, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak-to-valley surface roughness.

3.13.2 The relative surface factor, Y_{RrelT} is to be determined from Table 3.13.2. The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

Relative surface factor Y_{RrelT} *Table 3.13.2*

Material and heat treatment	$R_Z < 1$	$1 \le R_Z \le 40$
case hardened steels, through-hardened steels ($R_m \ge 800$ N/mm^2)	1.120	$1.674 - 0.529\ (R_Z + 1)^{0.1}$
normalised steels ($R_m < 800$ N/mm^2)	1.070	$5.306 - 4.203\ (R_Z + 1)^{0.01}$
nitrided steels	1.025	$4.299 - 3.259\ (R_Z + 1)^{0.0058}$

Notes: ① R_z — mean peak-to-valley roughness of tooth root fillets, in μm.

② If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied: $R_a = CLA = AA = R_Z/6$.

3.14 Size factor of bending stress Y_X

3.14.1 The size factor of bending stress, Y_X, takes into account the decrease of the strength with increasing size.

3.14.2 The factor Y_X mainly depends on:

(1) material and heat treatment;

(2) tooth and gear dimensions;

(3) ratio of case depth to tooth size.

3.14.3 The size factor Y_X is to be determined according to Table 3.14.3.

Size Factor of Bending Stress Y_X *Table 3.14.3*

Y_X	m_n	Status
1.00	$m_n \le 5$	Generally
$1.03 - 0.006\ m_n$	$5 < m_n < 30$	Normalized and through-hardened steels
0.85	$m_n \ge 30$	
$1.05 - 0.01\ m_n$	$5 < m_n < 25$	Surface hardened steels
0.80	$m_n \ge 25$	

3.15 Rim thickness factor, Y_B

The rim thickness factor, Y_B, is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis. Factor Y_B is to be determined as follows:

(1) for external gears: If

$S_R/h \ge 1.2$, $Y_B = 1$,

If $0.5 < \frac{S_R}{h} < 1.2$, $Y_B = 1.6 \cdot \ln(2.242\ \frac{h}{S_R})$

where: S_R — rim thickness of external gears, in mm;
h — tooth height, in mm.
The case $S_R/h \leq 0.5$ is to be avoided.

(2) for internal gears:
If $S_R/m_n \geq 3.5$, Y_B=1;
If $1.75 < S_R/m_n < 3.5$, $Y_B = 1.15 \cdot \ln(8.324 \frac{m_n}{S_R})$
where: S_R— rim thickness of internal gears, in mm.
The case $S_R/h \leq 1.75$ is to be avoided.

3.16 Deep tooth factor, Y_{DT}

The deep tooth factor, Y_{DT}, adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2.05 \leq \varepsilon_{\alpha n} \leq 2.5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:

If ISO accuracy grade ≤ 4 and $\varepsilon_{\alpha n} > 2.5$, $Y_{DT} = 0.7$;
If ISO accuracy grade ≤ 4 and $2.05 < \varepsilon_{\alpha n} \leq 2.5$, $Y_{DT} = 2.366 - 0.666 \cdot \varepsilon_{\alpha n}$; in all other cases, $Y_{DT} = 1.0$.

3.17 Safety factor for tooth root bending stress S_F

3.17.1 The safety factor for tooth root bending stress, S_F, can be assumed by taking into account the type of application. The safety factor for tooth root bending stress S_F is to comply with the following requirements:

main propulsion gears: $1.55 \leqslant S_F \leqslant 2.00$;
auxiliary gears: $1.40 \leqslant S_F \leqslant 1.45$.
For gearing of duplicated independent propulsion or auxiliary machinery, a reduced value can be assumed.

4 *Alignment*

4.1 Summary

At present, most gear box manufacturers require that during shaft alignment, static specific pressure of the gear bearing is not to exceed the specified value and static reaction difference of fore and aft bearings is not to exceed 20% of the total weight upon the two spans. Some manufacturers specify the dynamic limited pressure at the same time. It is proved through experience that under some circumstances, even if the conditions mentioned above are satisfied, the safety of the gearbox will not necessarily be ensured; on the contrary, even if the conditions mentioned above are not satisfied, it will not necessarily result in the failure of the gearbox. This covers design, alignment and installation of gearbox.

For gearbox is a part of the driving shafting, its alignment status is inevitably different with the different arrangement of shafting. Nevertheless, as a product, gearbox cannot be changed with the different arrangement of the shafting. The design of gearbox, such as arrangement of bearing, height of the bearing blocks, opening arrangement of sliding bearing pillow etc., is determined through dynamic resultant of gear force, so its safe operation when fitted onboard ship can be ensured.

4.2 Alignment calculation including gear force

4.2.1 The force of bearing in operation condition

When the gearbox is in static condition, only vertical static counterforce goes with the supporting bearing. Considering the influence of gearbox expansion in thermal state, the vertical static counterforce also goes with the supporting bearing. But when in operation condition, due to the influence of the gear force, not only supporting force changes, but the acting direction changes.

4.2.2 Calculation for dynamic resultants

Take the X-axis as along the gear shaft centerline, and the positive direction is from aft to fore wheel bearings. The Y-axis is perpendicular to the X-axis, with the upward direction as positive direction. The direction of Z-axis is determined by the right-hand rule.

Take the angle between the Y-axis and the line connecting gear engaged point and driven gear center as ψ, with the clockwise direction as positive direction.

θ_f and θ_a are angles between the Z-axis and the dynamic resultants on fore and aft bearings, with the counter-clockwise direction as positive direction.

L_1 is the distance between gear centerline and aft bearing; L_2 is the distance between gear centerline and fore bearing.

Take the upward direction (Y direction) as positive for counterforce on bearings; take the right direction (Z direction) as positive for counterforce on bearings while observed from aft to fore bearings.

Figure 4.2.2(1) shows the various forces that the final pinion with double gear ratio acts on wheel.

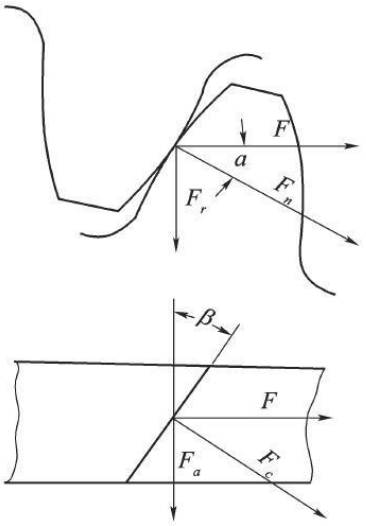


Figure 4.2.2(1) Forces acting on pinion

For spur gear and single helical gear, the dynamic resultants acting on bearings and acting directions are calculated in accordance with the following formulae:

(1) Counterforce which gear tangential force acts on fore and aft bearings

Tangential force F_t acting on wheel is:

$$F_t = 2T_1/d_1 \quad \text{kN} \tag{1}$$

where: T_1 — transmission torque acting on pinion, in N·m:

$$T_1 = 9550P\ u_2/n_e \tag{2}$$

where: P — propelling power transmitted by the reduction gear of the gearbox, in kW;

n_e — rated speed of the main engine, in r/min;

u_2 —gear ratio;

d_1 — working diameter of pinion, in mm.

The component of tangential force F_t acting on wheel in the Z direction, F_{tz}, is:

$$F_{tz} = F_t \cos\psi = 2T_1 \cos\psi/d_1 \quad \text{kN} \tag{3}$$

The component of tangential force F_t acting on wheel in the Y direction, F_{ty}, is:

$$F_{ty} = F_t \sin\psi = 2T_1 \sin\psi/d_1 \quad \text{kN} \tag{4}$$

The counterforce which gear tangential force acts on fore bearing in the Z direction, F_{tzf}, is:

$$F_{tzf} = \pm 2T_1\ L_1\cos\psi/((L_1+L_2)\ d_1) \quad \text{kN} \tag{5}$$

The counterforce which gear tangential force acts on aft bearing in the Z direction, F_{tza}, is:

$$F_{tza} = \pm 2T_1\ L_2\cos\psi/((L_1+L_2)\ d_1) \quad \text{kN} \tag{6}$$

The counterforce which gear tangential force acts on fore bearing in the Y direction, F_{tyf}, is:

$$F_{tyf} = \pm 2T_1\ L_1\sin\psi/((L_1+L_2)\ d_1) \quad \text{kN} \tag{7}$$

The counterforce which gear tangential force acts on aft bearing in the Y direction, F_{tya}, is:

$$F_{tya} = \pm 2T_1\ L_2\sin\psi/((L_1+L_2)\ d_1) \quad \text{kN} \tag{8}$$

Observed from aft to fore bearings, when the driven wheel rotates counter-clockwise, formulae (5) and (6) take positive, formulae (7) and (8) take negative; when it rotates clockwise, formulae (5) and (6) take negative, formulae (7) and (8) take positive.

(2) Counterforce which gear radial force F_r acts on fore and aft bearings

Radial force F_r is:

$$F_r = F_t \tan\alpha_n / \cos\beta \quad \text{kN} \tag{9}$$

where: α_n — normal engaged angle, in °.

β — helix angle at spur helical gear, in °.

The component of radial force F_r in the Z direction, F_{rz}, is:

$$F_{rz} = F_r \sin\psi = F_t \tan\alpha_n \sin\psi / \cos\beta \quad \text{kN} \tag{10}$$

The component of radial force F_r in the Y direction, F_{ry}, is:

$$F_{ry} = F_r \cos\psi = F_t \tan\alpha_n \cos\psi / \cos\beta \quad \text{kN} \tag{11}$$

The counterforce which gear radial force acts on fore bearing in the Z direction, F_{rzf}, is:

$$F_{rzf} = F_t L_1 \tan\alpha_n \sin\psi/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{12}$$

The counterforce which gear radial force acts on aft bearing in the Z direction, F_{rza}, is:

$$F_{rza} = F_t L_2 \tan\alpha_n \sin\psi/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{13}$$

The counterforce which gear radial force acts on fore bearing in the Y direction, F_{ryf}, is:

$$F_{ryf} = F_t L_1 \tan\alpha_n \cos\psi/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{14}$$

The counterforce which gear radial force acts on aft bearing in the Y direction, F_{rya}, is:

$$F_{rya} = F_t L_2 \tan\alpha_n \cos\psi/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{15}$$

(3) Counterforce which gear axial force F_a acts on fore and aft bearings

Axial force F_a is:

$$F_a = F_t \tan\beta \quad \text{kN} \tag{16}$$

The counterforce which gear axial force acts on fore bearing in the Z direction, F_{azf}, is:

$$F_{azf} = \pm F_t d_1 \tan\beta \sin\psi /(2(L_1 + L_2)) \quad \text{kN} \tag{17}$$

The counterforce which gear axial force acts on fore bearing in the Y direction, F_{ayf}, is:

$$F_{ayf} = \pm F_t d_1 \tan\beta \cos\psi /(2(L_1 + L_2)) \quad \text{kN} \tag{18}$$

For formulae (17) and (18), if, observed from aft to fore bearings, the wheel rotates counter-clockwise and is right-hand teeth, F_{azf} and F_{ayf} are positive; if the wheel rotates counter-clockwise and is left-hand teeth, F_{azf} and F_{ayf} are negative; if the wheel rotates clockwise and is right-hand teeth, F_{azf} and F_{ayf} are negative; if the wheel rotates clockwise and is left-hand teeth, F_{azf} and F_{ayf} are positive.

F_{aza}, the counterforce which gear axial force acts on aft bearing in the Z direction, and F_{azf} are equal in magnitude and opposite in direction; F_{aya}, the counterforce which gear axial force acts on aft bearing in the Y direction, and F_{ayf} are equal in magnitude and opposite in direction.

(4) Counterforce which gear weight acts on fore and aft bearings

The counterforce which gear weight acts on fore bearing, R_{f1}, is:

$$R_{f1} = 0.0098\ G_1 L_1 /(L_1 + L_2) \quad \text{kN} \tag{19}$$

The counterforce which gear weight acts on aft bearing, R_{a1}, is:

$$R_{a1} = 0.0098\ G_1 L_2 /(L_1 + L_2) \quad \text{kN} \tag{20}$$

where: G_1— gear weight, in kg.

(5) Counterforce which flange output shaft acts on fore and aft bearings

Case 1: if the center of gravity of flange output shaft is between the fore and aft bearings, then: the counterforce which flange output shaft acts on fore bearing, R_{f2}, is:

$$R_{f2} = 0.0098\ G_2 L_3 /(L_3 + L_4) \quad \text{kN} \tag{21}$$

the counterforce which flange output shaft acts on aft bearing, R_{a2}, is:

$$R_{a2}=0.0098\ G_2L_4/(L_3+L_4) \qquad \text{kN} \qquad (22)$$

where, for formulae (21) and (22),

G_2—weight of flange output shaft, in kg;

L_3 —distance between the gravity center of flange output shaft and the aft bearing, in mm;

L_4—distance between the gravity center of flange output shaft and the fore bearing, in mm.

Case 2: if the center of gravity of flange output shaft is on the left of (behind) the aft bearing, then: the counterforce which flange output shaft acts on fore bearing, R_{f2}, is:

$$R_{f2}=-0.0098G_2L_3/(L_4-L_3) \qquad \text{kN} \qquad (23)$$

the counterforce which flange output shaft acts on aft bearing, R_{a2}, is:

$$R_{a2}=0.0098G_2L_4/(L_4-L_3) \qquad \text{kN} \qquad (24)$$

Dynamic resultants F_f, F_a acting on fore and aft bearings and acting direction θ_f, θ_a is:

$$F_f=\left[(F_{tzf}+F_{rzf}+F_{azf})^2+(F_{tyf}+F_{ryf}+F_{ayf}+R_{f1}+R_{f2})^2\right]^{1/2} \qquad \text{kN} \qquad (25)$$

$$\theta_f=tg^{-1}\left[(F_{tyf}+F_{ryf}+F_{ayf}+R_{f1}+R_{f2})/(F_{tzf}+F_{rzf}+F_{azf})\right] \qquad (°) \qquad (26)$$

$$F_a=\left[(F_{tza}+F_{rya}+F_{aza})^2+(F_{tya}+F_{rya}+F_{aya}+R_{a1}+R_{a2})^2\right]^{1/2} \qquad \text{kN} \qquad (27)$$

$$\theta_a=tg^{-1}\left[(F_{tya}+F_{rya}+F_{aya}+R_{a1}+R_{a2})/(F_{tza}+F_{rya}+F_{aza})\right] \qquad (°) \qquad (28)$$

where:

F_{tzf}, F_{tza}— counterforce which gear tangential force acts on fore and aft bearings in the Z direction, in kN, see formulae (5) and (6);

F_{tyf}, F_{tya} — counterforce which gear tangential force acts on fore and aft bearings in the Y direction, in kN, see formulae (7) and (8);

F_{rzf}, F_{rza} — counterforce which gear radial force acts on fore and aft bearings in the Z direction, in kN, see formulae (12) and (13);

F_{ryf}, F_{rya}— counterforce which gear radial force acts on fore and aft bearings in the Y direction, in kN, see formulae (14) and (15);

F_{azf}, F_{aza}— counterforce which gear axial force acts on fore and aft bearings in the Z direction, in kN, see formula (17);

F_{ayf}, F_{aya}— counterforce which gear axial force acts on fore and aft bearings in the Y direction, in kN, see formula (18);

R_{f1}, R_{a1}— counterforce which gear weight acts on fore and aft bearings, in kN, see formulae (19) and (20);

R_{f2}, R_{a2}— counterforce which flange output shaft acts on fore and aft bearings, in kN, see formulae (21), (22), (23) and (24);

F_f,F_a — dynamic resultants on fore and aft bearings, in kN;

θ_f, θ_a — acting angle of dynamic resultants on fore and aft bearings (°)

Obviously, due to the influence of gear force, under operation condition, dynamic resultants of fore and aft bearings of wheels and its acting direction are different from force of alignment calculation for shafting thermal state and its direction.

Dynamic resultants F_f, F_a acting on fore and aft bearings and acting direction θ_f, θ_a is:

$$F_f = \left[(F_{tzf})^2 + (F_{ryf} + F_{ayf} + R_{f1} + R_{f2})^2\right]^{1/2} \quad \text{kN} \quad (29)$$

$$\theta_f = \tan^{-1}\left[(F_{ryf} + F_{ayf} + R_{f1} + R_{f2})/F_{tzf}\right] \quad (°) \quad (30)$$

$$F_a = \left[(F_{tza})^2 + (F_{rya} + F_{aya} + R_{a1} + R_{a2})^2\right]^{1/2} \quad \text{kN} \quad (31)$$

$$\theta_a = \tan^{-1}\left[(F_{rya} + F_{aya} + R_{a1} + R_{a2})/F_{tza}\right] \quad (°) \quad (32)$$

where:

$$F_{tzf} = \pm 2T_1 L_1/((L_1+L_2)\, d_1) \quad \text{kN} \quad (33)$$

$$F_{tza} = \pm 2T_1 L_2/((L_1+L_2)\, d_1) \quad \text{kN} \quad (34)$$

$$F_{ryf} = F_t L_1 \tan\alpha_n/((L_1 + L_2)\cos\beta) \quad \text{kN} \quad (35)$$

$$F_{rya} = F_t L_2 \tan\alpha_n/((L_1 + L_2)\cos\beta) \quad \text{kN} \quad (36)$$

$$F_{ayf} = -F_{aya} = \pm F_t d_1 \tan\beta\cos\psi/(2(L_1 + L_2)) \quad \text{kN} \quad (37)$$

If the pinion is right above the wheel, then:

Figure 4.2.2(2) shows the counterforce on fore and aft wheel bearings when the pinion is right above the wheel.

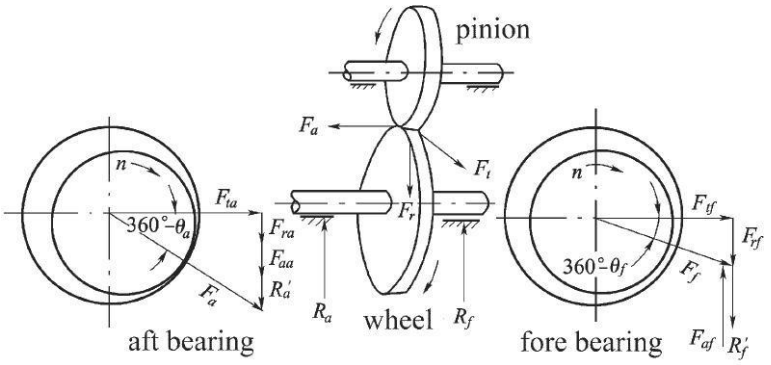


Figure 4.2.2(2) Counterforce on the wheel bearings

4.3 Influence of dynamic resultant

4.3.1 The interface of gear pillow is to be arranged in accordance with dynamic resultant direction.

(1) Bearing arrangement of straight tooth gear shaft

It may be seen from 4.2.2 that if it is straight tooth gear, there is no axial force, i.e., $F_a = 0$, then under the condition that bearing span is same or close, dynamic resultant and its direction is determined by the counterforce of shafting alignment and its direction. Where the counterforce of fore and aft bearings of delivery gear through alignment of shafting is positive value and is less than 20%, dynamic resultant of the two bearings and its direction is basically the same, and gear shaft will not be distorted. But due to the act of tangential force of gear, the direction of dynamic resultant is not on the vertical position, but within the IV quadrant (when the shaft rotates clockwise), as shown in Figure 4.3.1(1). Therefore, in order to ensure the establishment of lubricant film of bearing, and to avoid scorification of pillow, consideration is to be taken for the correct position of pillow entering oil groove, i.e., the interface of pillow is to be turned counter-clockwise to about 70° to 100° in accordance with the position of dynamic resultants.

(2) Bearing arrangement of helical gear shaft

For helical gear, $F_a \neq 0$, the strength and direction of dynamic resultant of fore and aft bearings are different, especially, the change of acting direction is great as shown in Figure 4.3.1(2). In this case, gear shaft will be distorted. Simultaneously, in order to ensure the normal establishment of lubricant film of bearing, and to avoid scorification of pillow, the position of dynamic resultants is to be calculated separately, and the interface of pillow is to be turned counter-clockwise to about 70° to 100°.

(3) Gear shafts other than delivery gear shaft

Where sliding bearings are adopted for other bearings in driving gears, the counter force of each bearing and gear force is to be calculated, and then dynamic resultant and direction of each bearing is to be calculated. The interface of pillow is also to be turned counter-clockwise to about 70° to 100° in accordance with the position of dynamic resultants.

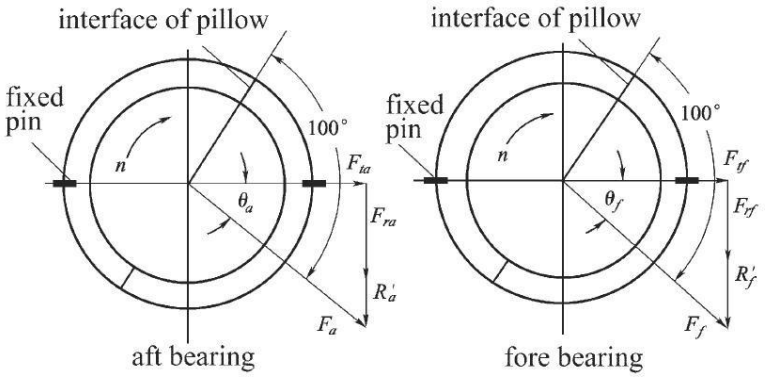


Figure 4.3.1(1) Stress of fore and aft bearings of spur gear

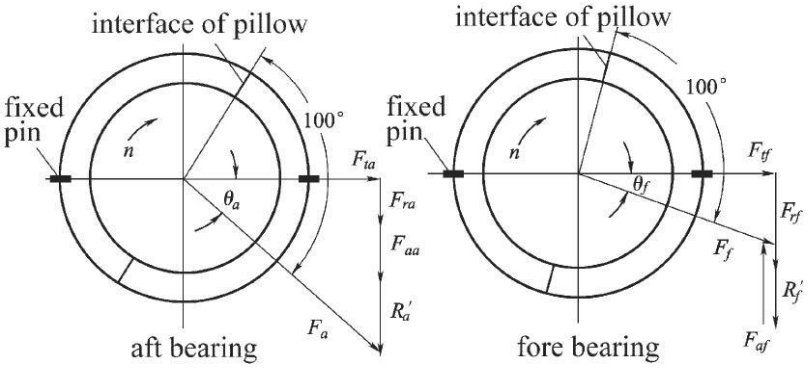


Figure 4.3.1(2) Stress of fore and aft bearings of helical gear

4.3.2 After the interface of pillows is determined according to the dynamic resultant, the counter force difference of alignment of two bearings may not be limited by 20% of the total weight.

When the driving shafting of gear is being aligned, the required load difference of fore and aft bearing of delivery gear is to be as little as possible. The maximum is not to exceed 20% of the total weight of the gear and shaft. Actually, if the interface of the gear pillow is determined in accordance with the dynamic resultant direction, the strength and direction of the dynamic resultant are mainly determined by the gear force under the condition that the alignment counterforce of two bearings is positive value (i.e., non-straight-line alignment). Therefore, during actual installation of shafting, it is safe even if the counter force difference of two bearings exceeds 20%. If the alignment counterforce of the fore bearing of delivery gear shaft on a ship is 28.95 kN, and the counterforce of the aft bearing is 10.61 kN, the difference is 2.7 times which greatly exceeds the defined 20%. However, the dynamic resultant of the fore bearing turns from 235 kN to 237 kN, and its acting angle turns from 348.2° to 346.4°; while the dynamic resultant of aft bearing turns from 283 kN to 277 kN, and its acting angle turns from 324.3° to 326.2°. Obviously, though the alignment counterforce difference of fore and aft bearing exceeds greatly the defined 20%, the influence of dynamic resultant and acting angle is little, i.e., the influence to dynamic specific pressure of the bearings and establishment of oil film is little, which is still safe.

4.3.3 Reducing the included angle of the dynamic resultants of fore and aft bearings can strengthen the engaging capability of gears and reduce noise.

The greater the included angle between dynamic resultant of fore and aft bearings, the greater the distorted angle of gear shaft; then the gear is distorted, which results in uneven contact along the facewidth, reducing the bearing capacity and increasing the contact stress of the gear. It will cause single side wearing of the gear, and even cause the gear broken event. Therefore, to ensure the parallel of the gear shaft, strengthen the engaging capability of gears and reduce noise, the included angle of the dynamic resultants of fore and aft bearings is to be reduced as far as possible. For driving shafting of the helical gear when it is being designed, the greater static counterforce value of the fore bearing is to be taken, so as to offset the influence of counterforce F_{af} of the axial force F_a acting upon the fore bearing.

In order to reduce the included angle of the dynamic resultants of fore and after bearing, when the gear is being designed, the F_a value is to be reduced as far as possible or $F_a = 0$, which may be achieved by the arrangement of herringbone gears, planetary gears or the symmetric arrangement of gears.

4.4 Alignment requirements to shafting

4.4.1 Parameters needed for alignment calculation of shafting

In order to facilitate alignment calculation of shafting, gearbox manufacturer is to provide following parameters:

Manufacturer:
Type:
Rated power: in kW
Rated speed: in r/min
Gear ratio:
Working diameter of pinion: in mm
Working diameter of wheel: in mm
Helix angle β of spur helical pinion, wheel: (°)
Normal engaged angle α_n: (°)
Structural size of pinion, wheel: in mm

Type of bearing:
Length of sliding bearing pillow: in mm
Open corner of sliding bearing pillow: (°)
Angle between the Y-axis and the line connecting gear engaged point and driven gear center ψ
Distance between gear centerline and fore bearing L_1
Distance between gear centerline and aft bearing L_2

4.4.2 The requirements to be satisfied for shafting alignment

(1) Rolling bearings

For rolling bearings, there is no need for establishment of lubricant film and the influence of gear force is considered during design, shafting alignment after the ship is loaded is to satisfy the following requirements:

① static load or dynamic load of bearing is not to exceed the permissible value;

② static counterforce difference or dynamic counterforce difference of fore and aft bearings is not to exceed the permissible value.

(2) Sliding bearings

For sliding bearings, due to establishment of lubricant film, if the gear force is included in design according to the requirements of this Chapter, shafting alignment after the ship is loaded is to satisfy the following requirements:

① not to exceed the dynamic specific pressure value of the bearing allowed for gearbox;

② changing of dynamic resultants not to affect the establishment of the lubricant film of gear bearing.

CHAPTER 11 SHAFTING AND PROPELLERS

Section 1 GENERAL PROVISIONS

11.1.1 *Application*

11.1.1.1 This Chapter is applicable to the shafting of ships propelled by diesel engines, steam turbines, gas turbines or electric propelling motors.

11.1.2 *General requirements*

11.1.2.1 Where the couplings are separate from the thrust shafts, intermediate shafts, tube shafts (i.e. the shaft which passes through the stern tube, but does not carry the propeller) and screwshafts, provision is to be made for the couplings to resist the astern pull so that no axial displacements of the couplings relative to the shafts may occur. Excessive stress concentration on the shafts is to be avoided.

11.1.2.2 Materials for shafting and propellers are to comply with the relevant requirements of ISC Rules for Materials and Welding.

The specified tensile strength of forgings for shafts is to be selected within the following general limits:

(1) for carbon and manganese steel, 400 to 760 N/mm^2. Where shafts may experience vibration stresses exceeding 90% permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength of 500 N/mm^2;

(2) for alloy steel, not exceeding 800 N/mm^2.

If the specified tensile strength exceeds the limitation value in 11.1.2.2(1) and (2) of this Chapter, calculation of shaft diameter is to comply with the provisions in 11.2.2.1 of this Chapter and calculation of permissible vibration stress is to comply with the provisions in 12.2.3.3, Chapter 12 of this PART.

For shaft couplings, nodular graphite cast iron may also be accepted.

11.1.2.3 The main propulsion shafting together with its transmission gears are to be capable of withstanding sufficient astern power.

For the main propulsion shafting with reduction gears, controllable pitch propellers or electric propelling motors, running astern are not to lead to the overload of main engines.

11.1.2.4 The sliding bearing temperature in the main propulsion shafting and transmission gearing is not to exceed 70℃, and not to exceed 80℃ if roller bearing is fitted.

11.1.2.5 The certificate requirements and product survey of shaft, bearing, coupling, propeller, transverse propulsion arrangement, Z propulsion arrangement and shafting connecting bolt are to comply with relevant requirements in Chapter 3, PART ONE of the Rules.

11.1.2.6 Alternative calculation methods may be considered by ISC. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections. Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given in Section 2 of Chapter 11 and Section 2 of Chapter 12.

11.1.3 *Vibration and Alignment of Shafting*

11.1.3.1 The shafting is also to comply with the requirements for shafting vibration and alignment in Chapter 12 of this PART.

11.1.4 *Plans and documents*

11.1.4.1 The following plans and documents of shafting and propellers are to be submitted for approval:

(1) Arrangement of Shafting;

(2) Thrust shaft, intermediate shaft, tube shaft (where applicable), and screwshaft;

(3) General arrangement of stern tube, including oil sealing gland and tube shaft bearings;

(4) Strength calculations for shafting, including calculations for the connection of couplings and strength calculations of bolts;

(5) Strength calculations for propellers;

(6) Propeller (including the clearances between the propeller and hull etc.);

(7) Oil shrink fitting of key or keyless propeller together with calculations (where applicable).

11.1.4.2 Detailed sizes and necessary parameters for verifying the calculations are to be indicated in plans.

Section 2 SHAFTING

11.2.1 *General requirements*

11.2.1.1 The minimum diameter of shafts determined by the formulae in this Section is to be checked for the allowable torsional vibration stress as specified in Chapter 12 of this PART.

11.2.2 *Diameter of shafts*

11.2.2.1 Low cycle fatigue criterion (typically < 10^4), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable.

The shaft diameter d is not to be less than the value determined by the following formula:

$$d = FC \sqrt[3]{\frac{N_e}{n_e}\left(\frac{560}{R_m + 160}\right)} \quad \text{mm}$$

where: F — factor for the type of propulsion installation:

F= 95 for intermediate shafts in turbine installations, diesel installations with hydraulic (slip type) couplings, electric propulsion installation;

F= 100 for all other diesel installations and all propeller shafts;

C — factor for the particular shaft design features (see Table 11.2.2.1) or calculated in accordance with the following formula;

$$C = \left[\frac{scf}{1.45}\right]^x$$

x — low cycle notch sensitivity. The chosen values are mainly representative for soft steels (R_m < 600), while the influence of steep stress gradients in combination with high strength steels may be underestimated;

scf — the stress concentration factors relative to the stress concentration for a flange with fillet radius of 0.08d (geometric stress concentration of approximately 1.45);

N_e — rated power transmitted through the shaft, in kW;

n_e — speed in revolution per minute of shaft at rated power, in r/min;

R_m — specified tensile strength of shaft material, in N/mm^2. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 760 N/mm^2 for R_m> 760 N/mm^2; when alloy steel is used, it is to be taken as 800 N/mm^2 for R_m> 800 N/mm^2. For special approval of alloy steel used for intermediate shaft material, the tensile strength of shaft material may be greater than 800 N/mm^2, but less than 950 N/mm^2, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness②and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of ISC Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm ^{2} for R_m> 600 N/mm^2.

Factor C for different design features *Table 11.2.2.1*

Intermediate shafts with					Thrust shafts external to engines		Propeller shafts		
Integral coupling flange	Keyless couplings fitted by oil shrink method	keyway	Radial hole	Longitudinal slot	The portion of thrust shafts outside the thrust collar at a length equal to the thrust shaft diameter, the remainder may be tapered down to the diameter required for the intermediate shaft	In way of axial bearings where roller bearing is used as thrust bearing	Flange mounted or keyless taper fitted propeller shafts	Key fitted propeller shafts	The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead
1.0①	1.0⑦	1.10②⑤⑧	1.10③⑤	1.20④⑤	1.10	1.10	1.22	1.26	1.15

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

Notes:

① The fillet radius at the base of the flange is not to be less than 0.08*d*.

② For over a length of at least 0.2*d* of the shaft from the ends of keyway and, the diameter of the shaft is to be increased by taking C = 1.10. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. The fillet radius in the transverse section at the bottom of the keyway are not to be less than 0.0125*d*.

③ For over a length of at least 0.2*d* of the shaft from the ends of hole and, the diameter of the shaft is to be increased by taking C = 1.10. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. The diameter of the hole is not to be greater than 0.3*d*. The intersection between a radial and an eccentric axial bore is not applicable, as shown in the figure below.

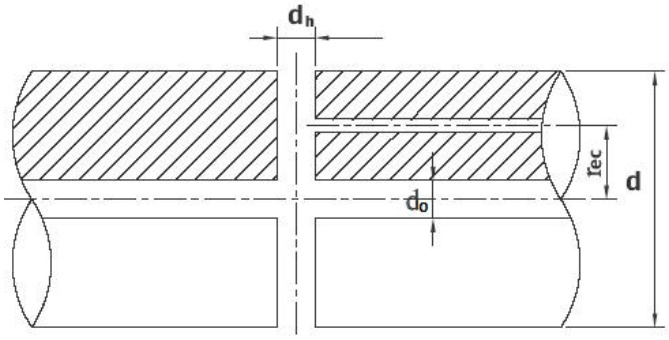


Figure 11.2.2.1 Intersection Between a Radial and an Eccentric Axial Bore

④ For over a length of at least 0.3*d* of the shaft from the longitudinal slot and its ends, the diameter of the shaft is to be increased by taking C = 1.20. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. In general, slot length is to be less than 0.8*d*, width is to be more than 0.15*d* and inner diameter is to be less than 0.7*d*. The end rounding of the slot is not to be less than half of the slot width and the quantity of slot is not to be more than 3. Slots at respectively 180º apart for 2 slots, and slots at respectively 120º apart for 3 slots. An edge rounding is preferably to be avoided as this increases the stress concentration slightly.

⑤ For shaft having several design features, the factor is to be the product of several factors.

⑥ Where, *d* is calculated with C = 1.0.

⑦ Where shafts may experience vibratory stresses exceeding 90% the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2%.

⑧ Keyways are in general not to be used in installations with a barred speed range.

11.2.2.2 Screwshafts or tube shafts forward of the aft peak bulkhead may be gradually reduced to the diameter of the intermediate shaft.

11.2.2.3 The diameter of the screwshaft determined in accordance with the formula in 11.2.2.1 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2.5 times the diameter of the screwshaft, whichever is the greater.

11.2.2.4 Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

11.2.3 *Hollow shafts*

11.2.3.1 For shafts where the bore d_0 is greater than 0.4*d*, the actual external diameter d_a of the shaft is not to be less than that determined by the following formula:

$$d_a = d\sqrt[3]{\frac{1}{1-\left(\frac{d_0}{d_a}\right)^4}} \quad \text{mm}$$

where: *d* — shaft diameter determined by 11.2.2.1 of this Section, in mm;

d_0— actual bore of the shaft, in mm.

11.2.3.2 The edges of slots and holes in the shafts are to be smooth and without any traces of machining.

11.2.3.3 For ships engaged only in harbor service, the minimum diameter of the shafts may be reduced by 3%.

11.2.4 *Shaft liners*

11.2.4.1 The thickness *t* of bronze shaft liners shrunk on tube shafts or screwshafts, in way of the bushes, is not to be less than:

$$t = 0.03d + 7.5 \quad \text{mm}$$

where: *d* — diameter of tube shaft or screwshaft in way of the bushes, in mm.

The thickness of stainless steel liners, where fitted, is to be one-half that obtained above, but not less than 6

mm.

11.2.4.2 The thickness of a continuous liner between the bushes may be somewhat reduced, but is not to be less than 0.75*t*.

11.2.4.3 Continuous liners are to be generally cast in one piece. Where necessary, they may consist of two or more pieces, but these are to be butt-welded by reliable methods to prevent water ingress.

11.2.4.4 Where the portion of the shaft between any two lengths of the liner is protected with glass-reinforced plastics or other industrial plastics, the protection at the junction of the liner ends is to be of such a construction as to prevent the shaft from water ingress. In general, semicircular groove may be at the junction of the liner ends which is protected with several layers of glass-reinforced plastics or other industrial plastics and secured with copper wire or stainless steel wire. The connection portions are not to be located within the bearing range.

11.2.4.5 Shaft liners which are cast in one piece or consist of two or more lengths, are to be subject to hydraulic test to a pressure of 0.2 MPa after rough machining, and there is to be no crack or leakage.

11.2.4.6 Liners are to be carefully shrunk on, or forced on, to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

11.2.4.7 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

11.2.5 *Stern tubes and bearings*

11.2.5.1 The length of the bearing in the stern bush next to and supporting the propellers is to be as follows:

(1) For water lubricated bearings, the length of the bearing is not to be less than 4 times the rule calculated diameter for the screwshaft in way of the bearing. For water lubricated synthetic materials, if the design and materials of bearings comply with ISC provisions as demonstrated by tests, the length of the bearings may be appropriately reduced, but not less than 2 times the rule diameter of the shaft in way of the bearing. Synthetic materials of water lubricated stern tube bearings are to be type approved.

(2) For bearings which are white-metal lined and oil lubricated, the length of the bearing is not to be less than twice the rule calculated diameter for the screwshaft in way of the bearing. If the normal bearing pressure is less than 0.8 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is to be not less than 1.5 times the actual diameter.

(3) For bearings of synthetic rubber, reinforced resin or plastics materials which are approved for use as oil lubricated stern bush bearings, the length of the bearing is to be not less than twice the rule diameter of the shaft in way of the bearing. If the normal bearing pressure is less than 0.6 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is to be not less than 1.5 times the actual diameter. Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.

Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

(4) The length of a grease lubricated bearing is to be not less than 4.0 times the rule diameter of the shaft in way of the bearing.

(5) For bearings which are lined with other materials or lubricated by other methods, background for adopting its bearing length is to be provided, e.g. test results such as expansion characteristics and bearing capability of bearing material or service experience.

11.2.5.2 Forced water lubrication is to be provided for all bearings lined with rubber or plastics and for those lined with lignum vitae where the shaft diameter is 400 mm or over. A shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the stern tube where the water supply enters the stern tube forward of the bulkhead.

11.2.5.3 Bearings which are oil lubricated are to be fitted with an approved oil sealing gland.

11.2.5.4 Where a gravity tank supplying lubricating oil to the stern bush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.

11.2.5.5 Where stern bush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the stern tube or by other suitable means.

11.2.5.6 Stern tubes are to be subject to hydraulic test to a pressure of 0.2 MPa before being fitted on board ship.

Section 3 SHAFT TRANSMISSION UNITS

11.3.1 *Application*

11.3.1.1 The requirements of this Section apply to couplings, hydraulic transmission arrangements, clutches, Z propulsion arrangement, transverse propulsion arrangement (if applying for additional notation) as well as controllable pitch propeller blade actuators. For transmission gearing, see Chapter 10 of this PART.

11.3.2 *Couplings*

11.3.2.1 Flange couplings are to comply with the following requirements:

(1) The thickness of coupling flanges is not to be less than 20% of the intermediate shaft diameter required in 11.2.2.1 of this Chapter, nor is it to be less than the diameter of the fitting coupling bolts whose minimum tensile strength is equivalent to that of the shafts. The fillet radius at the base of the coupling flange is not to be less than 8% of the actual diameter of the shaft at the coupling. Special consideration will be given for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

(2) Where the propeller is attached to the screwshaft by means of a coupling flange, the thickness of the flange is not to be less than 25% of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of coupling flange is not to be less than 12.5% of the actual diameter of the shaft at the coupling.

(3) Fillets are to have a smooth finish and not to be recessed in way of nuts and bolt heads. The fillet may be formed of multiradii in such a way that the stress concentration factor is not to be greater than that for a circular fillet with radius 0.08 times the actual shaft diameter.

11.3.2.2 Where the coupling is fitted to the shaft with a key and the torque is transmitted through the key, the effective sectional area of the key in shear is not to be less than that determined by the following formula, and the tensile strength of the key material is to be equal to or greater than that of the shaft material:

$$BL \geq \frac{d^3}{2.6 d_m} \qquad \text{mm}^2$$

where: B — breadth of key, in mm;

L — effective length of key, in mm;

d — diameter of intermediate shaft determined in 11.2.2.1 of this Chapter, in mm;

d_m — diameter of shaft at mid-length of the key, in mm.

11.3.2.3 Keyless couplings fitted by oil shrink method are to meet the following requirements:

(1) Muff couplings are to have a capacity of transmitting a torque which is 2.8 times the mean torque and their equivalent stress of the maximum shrinkage allowance is not to be more than 70% of the yield stress of the muff material.

(2) For general couplings which are not covered in (1) above, the pull-up S or shrinkage allowance $\delta$is to meet the following requirements:

$$S_1 \leq S \leq S_2 \qquad \text{mm}$$

$$\delta_1 \leq \delta \leq \delta_2 \qquad \text{mm}$$

$$S_1 = \frac{\delta_1}{K} = \frac{1}{K}\left[\frac{1672 N_e}{A n_e}(c_1 + c_2) + 0.03\right] \qquad \text{mm}$$

$$S_2 = \frac{\delta_2}{K} = \frac{0.034 \times 10^{-4}}{K} \mathrm{R}_{eH} d_1 (c_1 + c_2) \frac{K_2^2 - 1}{\sqrt{3K_2^4 + 1}} \qquad \text{mm}$$

where: S_1 — minimum axial pull-up, in mm;

S_2 — maximum axial pull-up, in mm;

δ_1 — minimum shrinkage allowance, in mm;

δ_2 — maximum shrinkage allowance, in mm;

K — taper of the shaft for shrink-fit;

N_e — rated power transmitted by the shaft, in kW;

n_e — speed of the shaft at N_e, in r/min;

A — theoretical contact area of the shrinkage surface, in mm^2;

$c_1 = \frac{1 + K_1^2}{1 - K_1^2} - \mu_1$;

$$c_2 = \frac{K_2^2 + 1}{K_2^2 - 1} + \mu_2;$$

$$K_1 = \frac{d_0}{d_1};$$

$$K_2 = \frac{d_2}{d_1};$$

d_0 — bore diameter of the shaft, in mm;
d_1 — mean diameter of the shaft within the contact length, in mm;
d_2 — mean outside diameter of the coupling within the contact length, in mm;
$\mu_1 = \mu_2 = 0.3$;
R_{eH} — specified yield stress of the coupling material, in N/mm^2.

11.3.2.4 Clamp couplings are to meet the following requirements:
(1) Clamp couplings are to have a strength at least equal to the required strength of the intermediate shaft.
(2) The clamp coupling is to be provided with a key. For couplings transmitting thrust, a satisfactory axial locking device is to be provided.
(3) Torque is to be transmitted by the frictional moment resulting from clamping and the key. The frictional moment is not to be less than the rated torque to prevent track slip and the sizes of the key are not to be less than 2/3 of those determined by the formula in 11.3.2.2.
(4) The clamping length of the coupling is normally to be at least 2.4 times shaft diameter.
11.3.2.5 Where other types of couplings or connections are used for torque transmission, background of test results or service experience are to be provided for the purpose of examining their reliability.

11.3.3 *Coupling bolts*

11.3.3.1 For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter d_f is not to be less than that given by the following formula:

$$d_f = 0.65\sqrt{\frac{d^3(R_m + 160)}{DZR_{mb}}} \quad \text{mm}$$

where: d — Rule diameter of the solid intermediate shaft, in mm, in accordance with the requirements of Chapter 14 of this PART, taking into account ice strengthening requirements where applicable;
Z — number of bolts;
D — pitch circle diameter, in mm;
R_m — tensile strength of the intermediate shaft material for calculation, in N/mm^2;
R_{mb} — tensile strength of the fitted coupling bolts material taken for calculation, in N/mm^2, where: $R_m \le R_{mb} \le 1.7\ R_m$, but not higher than 1,000 N/mm^2.

11.3.3.2 Where it is proposed to use non-fitting bolts for connections, the diameter d_n at the root of thread of the bolts is not to be less than that determined by the following formula:

$$d_n = 25\sqrt{\frac{N_e \times 10^6}{n_e DZR_{mb}}} \quad \text{mm}$$

where: N_e — rated output transmitted by the shaft, in kW;
n_e — speed of the shaft at N_e, in r/min;
other symbols are as defined in 11.3.3.1 of this Section.
The prestressing force and workmanship of ordinary bolts are to be provided for information.

11.3.3.3 Bolts connecting propellers and screwshafts are to be fitting bolts, the diameter of which is to be increased by 5% of that determined in 11.3.3.1 of this Section.
11.3.3.4 For ships engaged only in harbour service, the diameter of the connecting bolts may be reduced by 4%.
11.3.3.5 The diameter of the fitting bolts at the joining faces of the couplings within the crankshaft and thrust shaft/crankshaft is to be increased by 5% of that determined by 11.3.3.1 of this Section.

11.3.4 *Clutches and control devices*

11.3.4.1 The friction elements of clutches for reversible gearing are not to give any slip in normal running. While the clutch is disengaged, the propulsion shafting is not to be dragged along by the driving shaft.
11.3.4.2 The maximum torque transmitted by the clutch is, in general, not to be less than 1.5 times the

rated torque of the main engine.

11.3.4.3 The flexible clutches controlled by air pressure are to be provided with air charging pressure gauges, signal devices for indicating clutching and declutching of the clutches and alarm devices for giving warning of high and low air pressures.

11.3.4.4 An emergency device for air charging is to be fitted to the system which supplies air to the pneumatic flexible clutch.

11.3.4.5 For reversible clutches, the time required for reversal is not to be more than 15 s.

11.3.4.6 In single screw ships having clutches, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of the clutches.

11.3.5 *Hydraulic transmissions*

11.3.5.1 In single screw ships having emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of the hydraulic transmission systems.

11.3.5.2 The lubricating oil system of hydraulic transmission arrangements is to be separate from other systems. The system is to consist of filters, coolers, drain tanks, etc. In the case of hydraulic gear transmission, in addition, magnetic filters are to be provided in the system.

11.3.5.3 Hydraulic transmission arrangements are to be provided with separate stand-by pumps. For propulsion systems with twin-engine and twin-screw, one stand-by pump may be accepted.

11.3.5.4 In addition to thermometers and pressure gauges, the lubricating oil system of hydraulic transmission arrangements is to be fitted with alarm devices for giving warnings of an excessive temperature and appreciable reduction in pressure of the oil supply.

11.3.5.5 The runners and impellers of hydraulic couplings are to be statically balanced. Furthermore, it is recommended that the runners and impellers be dynamically balanced.

11.3.5.6 Signal devices for indicating oil charging and discharging are to be fitted at the control positions of hydraulic transmission arrangement.

11.3.5.7 The hydraulic transmission arrangements may be controlled at the engine side and in the centralized control station or in the bridge. Where two or more control devices are fitted, they are to be interlocked one another.

11.3.5.8 In the case of multiple engines operating on one screwshaft, an interlocking device is to be provided in the control gear of the hydraulic transmission arrangement to prevent them from being filled with oil when the engines are in opposite directions.

11.3.5.9 At the centralized control station of hydraulic transmission, a tachometer showing the speed of the screwshaft and an indicator showing the direction of its rotation are to be fitted.

11.3.6 *Transmission devices for controllable pitch propeller*

11.3.6.1 The hydraulic transmission system of controllable pitch propeller blade actuators is to be provided with a separate stand-by pump having a capacity of not less than that required for power hydraulic oil pump during normal operation of one hydraulic transmission system of controllable pitch propeller. One independent stand-by pump may be common to hydraulic transmission system of controllable pitch propeller of duplicated propulsion shafting system. Where each hydraulic transmission system of controllable pitch propeller is provided with independent hydraulic pump, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.

For propulsion plants up to 200 kW, one power-driven pump set is sufficient provided that, in addition, a hand-operated pump is fitted for controlling the blade pitch and that this enables the blades to be moved from the ahead to the astern position in a short enough time.

11.3.6.2 Pitch angle indicators are to be fitted both at the engine room control station and in the bridge. The deviation from the actual pitch angle is not to exceed ±1°.

11.3.6.3 The control system in the engine room is to be interlocked with that in the bridge. For control systems other than those actuated by mechanical devices, a stand-by manual control is to be fitted at the engine side.

11.3.6.4 The control system of hydraulic controllable pitch propeller blade actuators is to be such that the blade pitch can be altered efficiently and accurately.

11.3.6.5 Under any working conditions, the blade position of controllable pitch propellers is to be stable. Its fluctuation at 0° pitch angle is not to exceed ±0.5°.

11.3.6.6 At the rated speed of the propeller, the time required for the change of pitch angle from 1/3 positive maximum (or 1/3 negative maximum) to 1/3 negative maximum (or 1/3 positive maximum) is not to exceed 15 s.

11.3.6.7 The pitch adjusting range of controllable pitch propeller is to ensure that the main engine will provide rated power under rated speed and specified astern power.

11.3.6.8 Thread core diameter d_k of blade fastening bolts is not to be less than the value obtained from following formula:

$$d_k = 2.6\sqrt{\frac{W_{0.35R}R_{P0.2}\alpha_A}{dZR_{eH}}} \quad \text{mm}$$

where: $W_{0.35R}$ — section modulus of cylindrical section at radius 0.35R, in mm^3;

$$W_{0.35R} = 0.11\,(Bt^2)_{0.35R}$$

where: B — breadth of blade on section at radius 0.35R, in mm;

t — maximum thickness of blade on section at radius 0.35R, in mm.

$R_{P0.2}$ — 0.2% proof stress of propeller material, in N/mm^2;

α_A — tightening factor for retaining bolts, = 1.2 to 1.6, depending on the method of tightening used;

d — diameter of pitch circle of bolt hole of fastening bolts, in mm;

Z — number of bolts;

R_{eH} — yield strength of fastening bolts, in N/mm^2.

11.3.6.9 Under following conditions, the controllable pitch propeller is to have alarm function:

(1) pressure of hydraulic system is too low;

(2) oil level of main hydraulic oil tank is too low;

(3) oil filter is blocked;

(4) pressure of boss lubricating oil is too low (except for grease lubricating method);

(5) temperature of hydraulic oil is too high;

(6) pitch adjusting function fails;

(7) power supply of control system fails.

11.3.6.10 Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

11.3.6.11 Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades does not change or assumes a final position slowly enough to allow the emergency control system to be put into operation.

11.3.6.12 Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to remain in operation should the remote control system fail. It is recommended that a device be fitted which locks the propeller blades in the “ahead” setting.

In case of emergent fixed propeller condition, effective measures are to be provided to prevent pitch adjustment.

11.3.6.13 Before being installed on board, the pipe lines and pressure elements of hydraulic transmission system and control system for controllable pitch propellers are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, the system is to be tested to 1.25 times the working pressure for tightness, but need not exceed the design pressure plus 7 MPa.

11.3.6.14 Controllable pitch propeller and its main parts are to be subject to material test and non-destructive test according to the relevant requirements of ISC Rules for Materials and Welding.

11.3.6.15 A sealing is to be inserted between the propeller blade and the propeller boss to prevent the ingress of sea water and sand as well as the leakage of lubricating grease.

11.3.6.16 The inside of the propeller bosses is to be filled up with lubricating grease.

11.3.7 *Z propulsion arrangement*

11.3.7.1 Z propulsion arrangement is to be provided with means to control its propulsion direction from bridge, machinery control station (if any) and on the spot. Indicators of direction of thrust are to be provided in these control locations.

11.3.7.2 When the output shaft of main engine and input shaft of Z propulsion arrangement are not in the same level, universal couplings are to be provided in pair with same angle which is in general not to be more than 10°.

11.3.7.3 If Z propulsion arrangement has electric or electro-hydraulic power equipment of steering turning device , spare power equipment or other emergency control measures are to be provided.

If there are two or more Z propulsion arrangement on the ship, spare power equipment is not necessary.

11.3.7.4 The diameters of input shaft, vertical shaft and propeller shaft of Z propulsion arrangement are not to be less than the value obtained from calculation according to the formula in 11.2.2.1 of this Chapter.

11.3.7.5 Shafting vibration calculation of Z propulsion arrangement is to comply with the requirements in Chapter 12 of this PART.

11.3.7.6 Strength and installation of propeller of Z propulsion arrangement are to comply with the requirements in Section 4, Chapter 11 of this PART.

11.3.7.7 All alarms related to system failure are to be shown on maneuvering console. Z propulsion arrangement is to have alarm function under following conditions:
(1) low pressure of lubricating oil;
(2) high temperature of lubricating oil;
(3) low level of hydraulic oil;
(4) low pressure of hydraulic oil;
(5) high temperature of hydraulic oil (if fitted with oil cooler);
(6) too high pressure difference of hydraulic oil filter (if fitted with oil filter);
(7) low pressure of clutch.
11.3.7.8 On completion of manufacture of parts of Z propulsion arrangement such as upper and lower gearbox, rotating rudder gearbox and rudder post, 0.2 MPa hydraulic test is to be carried out and tightness test is to be carried out after assembly. Tightness test may be carried out using liquid with 0.1 MPa pressure, and 0.03 MPa compressed air may be used for test examination by means of applying soap liquid. No leakage is permitted.
11.3.7.9 Hydraulic pipes are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, they are to be tested together with fittings to 1.25 times the design pressure for tightness.
11.3.7.10 Z propulsion arrangement together with its main parts and accessories are to be subject to material test and non-destructive test according to ISC Rules for Materials and Welding.
11.3.7.11 Steering gear of Z propulsion arrangement is to comply with the requirements of Section 1, Chapter 13 of this PART.

11.3.8 *Transverse propulsion arrangement*

11.3.8.1 Transverse propulsion arrangement is to have sufficient transverse thrust to satisfy the working requirements of navigation at low speed and docking and leaving wharf.
11.3.8.2 Material and test of transverse propulsion arrangement and its components are to comply with the relevant requirements of ISC Rules for Materials and Welding.
11.3.8.3 Diesel engines driving transverse propulsion arrangement are to comply with the relevant requirements in Chapter 9 of this PART.
11.3.8.4 Motor and distribution system of driving transverse propulsion arrangement are to comply with the relevant requirements in PART FOUR of the Rules.
11.3.8.5 The design of shafting together with its parts and propeller is to comply with the relevant requirements of this Chapter.
11.3.8.6 The thickness of tunnel of transverse propulsion arrangement is not to be less than the adjacent part of the hull.
11.3.8.7 The shaft sealing box is to be installed to prevent water so as to protect steel shafts from sea water.
11.3.8.8 Alarm is to be in the bridge with individual or groupwise indicator for the following faults:
(1) overload of prime mover and servo unit;
(2) power failure of remote control system;
(3) power failure of alarm system;
(4) low level in lubrication oil tank (if fitted);
(5) low lubrication oil pressure (if forced lubrication oil system);
(6) low level in hydraulic supply tank;
(7) low pressure in hydraulic system.
11.3.8.9 Individual indication in the bridge is required for:
(1) running and stop of prime mover;
(2) propeller pitch for controllable pitch propeller plants;
(3) direction of rotation and r.p.m. for fixed propeller plants.
11.3.8.10 It is to be possible to stop the transverse propulsion arrangement from the bridge by means of a system independent of the remote control system.
11.3.8.11 Instrumentation and automation are also to comply with the relevant requirements of PART SEVEN of the Rules.

Section 4 PROPELLERS

11.4.1 *General requirements*

11.4.1.1 Propellers are to be subject to surface inspection and size verification as well as to static

balancing test. For built-up propellers and controllable pitch propellers, the static balancing test is to be carried out respectively after machining and assembling.

11.4.1.2 Blade fastening studs of built-up propellers are to be made of forged steel having a tensile strength not less than 400 N/mm^2.

11.4.1.3 Fasteners (studs, nuts, etc.) for propellers and for their accessories are to be fitted with reliable devices to prevent loosening and corrosion.

11.4.2 *Clearances between propeller and hull*

11.4.2.1 For the purpose of modifying the effect of propeller excitation on hull, the necessary minimum clearances between the propeller and the hull are to be provided as specified in 2.14.4 of PART TWO of the Rules.

11.4.3 *Thickness of propeller blades*

11.4.3.1 The thickness of propeller blades t (at 0.25 *R* and 0.6 *R* for solid propellers, and at 0.35 *R* and 0.6 *R* for controllable pitch propellers) is not to be less than that calculated by the following formula:

$$t = \sqrt{\frac{Y}{K - X}} \qquad \text{mm}$$

where: Y — power coefficient, to be obtained from 11.4.3.2 of this Section;

K — material coefficient given in Table 11.4.3.1;

X — speed coefficient, to be obtained from 11.4.3.3 of this Section.

Propeller material coefficient K *Table 11.4.3.1*

Material	tensile strength R_m (N/mm^2)	Material density G (g/cm^3)	Material coefficient K
Carbon steel and alloy steel	400	7.9	0.57
Ferritic and martensitic stainless steel	500	7.7	1.04
Austenitic stainless steel	450	7.9	1.04
Cu1 manganese bronze	440	8.3	1
Cu2 nickel-manganese bronze	440	8.3	1
Cu3 nickel-aluminum bronze	590	7.6	1.38
Cu4 manganese-aluminum bronze	630	7.5	1.17

Note: For materials other than specified in the above Table, the value K may be determined by making reference to those given in the Table.

11.4.3.2 Power coefficient Y is to be calculated by the following formula:

$$Y = \frac{1.36 A_1 N_e}{Z b n_e}$$

where: $A_1 = \frac{D}{P}(K_1 - K_2 \frac{D}{P_{0.7}}) + K_3 \frac{D}{P_{0.7}} - K_4$;

D — propeller diameter, in m;

P — pitch at the section under consideration, in m;

$P_{0.7}$— pitch at 0.7 R, in m;

R — propeller radius, in m;

K_1, K_2, K_3, K_4— coefficients given in Table 11.4.3.2;

N_e— rated power of the main engine, in kW;

Z — number of blades;

b — blade width at the section under consideration, in m;

n_e— speed of the propeller at rated power of main engine, in r/min.

For aerofoil sections with trailing edge washback, the value of A_1 obtained from above formula is to be increased by 30%. The trailing edge washback is the offset of the trailing edge of the tangent plane of the propeller blade in respect to the pitch baseline (external chord) of the blade face, as shown in Figure 11.4.3.2, e.g. 0.6R without washback and 0.25R with washback.

Coefficient K values in way of different diameters of propeller *Table 11.4.3.2*

K / r	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
0.25R	634	250	1410	4	82	34	41	380
0.35R	520	285	1320	16	64	28	57	420
0.60R	207	151	635	34	23	12	65	330

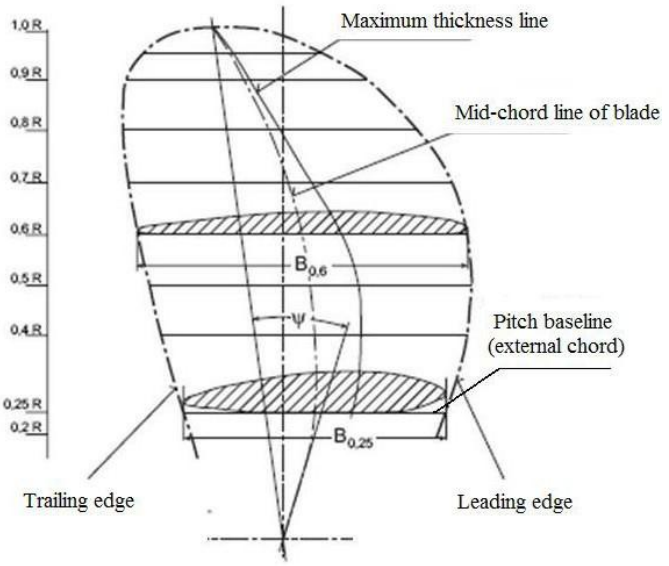


Figure 11.4.3.2

11.4.3.3 Speed coefficient X is to be calculated by the following formula:

$$X = \frac{A_2 G A_d n_e^2 D^3}{10^{10} Zb}$$

where: $A_2 = \frac{D}{P}(K_5 + K_6\varepsilon) + K_7\varepsilon + K_8$

D, P, n_e, Z and b as defined in 11.4.3.2 of this Section;

ε — rake angle of propeller blade, in degrees. The value of the rake angle is positive for backward rake and negative for forward rake. The rake angle is, as shown in the side view of propeller, is an angle taken in one of the following three conditions:

— ε_1 and ε_2 are backward rake angles: the more backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(1));

— ε_1 and ε_2 are forward rake angles: the less forward one is to be taken ($\varepsilon = \varepsilon_2$, as shown in Figure 11.4.3.3.3(2));

— ε_1 and ε_2 are rake angles on both sides of the centreline: the backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(3)).

ε_1 is the angle measured from the line perpendicular to shaft centerline to the tangent to the backward thickness line at the radius 0.6R of the side projection of propeller blade;

ε_2 is the angle obtained by the following formula:

$$\varepsilon_2 = \tan^{-1}\frac{e}{R}$$

where: e — rake (radial inclination of blade section forward or backward from the reference line, taken as the distance between the blade tip projected on the propeller shaft and the intersection of the reference line and the propeller axis), in m;

R — the same as in 11.4.3.2.

K_5, K_6, K_7, K_8 — coefficients given in Table 11.4.3.2;

G — density of the propeller material, in g/cm^3;

A_d — expanded area ratio.

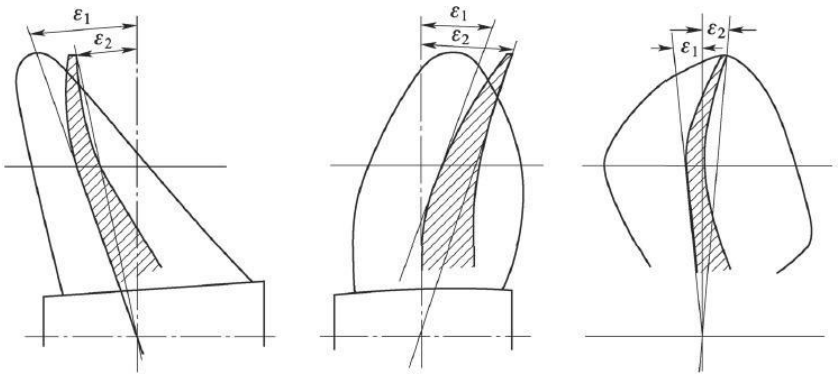


Figure 11.4.3.3 Rake Angle of Propeller Blade

11.4.3.4 The thickness of propeller blades is permitted to be calculated by some other appropriate methods, but background of test results or service experience is to be provided.

11.4.3.5 Depending on the condition of application of the propeller, detailed data of wake field in periphery of the propeller or blade thickness increase may be required.

11.4.4 *Fitting of propellers to screwshafts*

11.4.4.1 Where it is proposed to fit the propeller to the screwshaft with a flange, the diameter of flange bolts is to comply with the requirements of 11.3.3.1 and 11.3.3.3 of this Chapter, and the thickness of flanges is to comply with the provisions of 11.3.2.1(2) of this Chapter.

11.4.4.2 Where it is proposed to fit the propeller to the screwshaft with a key, the propeller boss is to be a good fit on the screwshaft cone. The length of the forward fitting surface is to be about the diameter of the screwshaft.

The taper of the coned end of screwshaft is not to exceed 1/10, and for keyless propellers fitted by oil injection method, such taper is not to exceed 1/15.

The intersection of cylindrical and conical portions of screwshafts is not to be shouldered or rounded. The forward end of the keyway in the screwshaft is to be smoothed and sled-runner shaped. In general, the shape and size may be in accordance with Figure 11.4.4.2, where $r_1 < r_2 < r_3 < r_4$, $AB = BC = CD = DF = x$ (x being depth of keyway). For r_1, r_2, r_3 and r_4, refer to the following:

$r_1 = x/8$, $r_2 = 3x/8$, $r_3 = 3x/4$, $r_4 = x$.

The values of r_5 are given in Table 11.4.4.2.

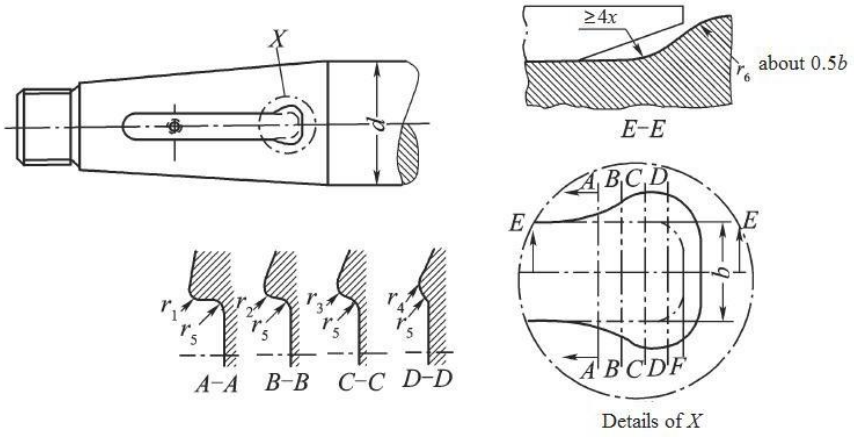


Figure 11.4.4.2

Values of r_5 **Table 11.4.4.2**

d (mm)	r_5 (mm)	d (mm)	r_5 (mm)
$d \leq 150$	3	$250 < d \leq 400$	5
$150 < d \leq 250$	4	> 400	6

The distance from the forward end of the keyway to the big end of conical portion of the shaft is not to be less than 0.2 times the diameter of the big end.

There is to be a clearance between the top of the key and the boss. The lateral sides of the key are to be in close contact with those of the keyways in the screwshaft and the propeller boss. The bottom of the keyways are to be provided with a smooth fillet, and the fillet radius is not to be less than 1.25% of the diameter of the big end of the cone.

Keys are to be secured to the shafts by screws. The forward screw is to be placed at least 1/3 of the length of the key from the end. The depth of the screw holes is not to exceed the diameter of screw holes, and the edges of the holes are to be beveled.

The outside diameter of the threaded end for the propeller retaining nut is not to be less than 60% of the calculated diameter of the propeller shaft.

11.4.4.3 Where the torques are transmitted completely by the keys, the effective sectional area of the key in shear is not to be less than the value determined by the following formula, and the tensile strength of the material is to be equal to or greater than that of the shaft material:

$$BL \geq \frac{d^3}{2.35 d_m} \qquad \text{mm}^2$$

where: B — breadth of the key, in mm;

L — effective length of the key, in mm;

d — diameter required for the intermediate shaft, in mm, to be taken as 800 N/mm^2 when the tensile strength of intermediate shaft material is greater than 800 N/mm^2 during calculation;

d_m — diameter of shaft at mid-length of the key, in mm.

11.4.4.4 The fitting of a keyed propeller is preferable to meet the following requirements, and the size of keys may be suitably reduced:

(1) the safety factor of friction force against sliding is not to be less than 1.0 at sea water temperature of 35°C;

(2) the inner surface pressure of propeller boss is not to be less than 20 MPa at sea water temperature of 15°C;

(3) the equivalent uniaxial stress at the inner surface of propeller boss is not to be more than 35% of the specified minimum yield stress of the material concerned at sea water temperature of 0°C.

11.4.5 *Fitting of keyless propeller by oil shrink method*

11.4.5.1 Where keyless fitting propellers with oil pressure, the axial pull-up length from propeller boss to shaft is to be in compliance with the requirements of 11.4.5.2.

11.4.5.2 The maximum equivalent uniaxial stress in the boss at 0°C based on the Mises-Hencky criterion is not to exceed 70% of the yield point or 0.2% proof-stress (0.2% offset yield strength) for the propeller material based on the test piece value. For cast iron, the value is not to exceed 30% of the nominal tensile strength.

Where keyless fitting propellers with oil pressure, the axial pull-up length S from propeller boss to shaft may also meet the formulae given below:

Minimum required surface pressure at 35°C:

$$P_{35} = \frac{S_F T}{AB}\left(-\frac{S_F K}{2} + \sqrt{\mu^2 + B\left(\frac{F_v}{T}\right)^2}\right) \qquad \text{N/mm}^2$$

Minimum pull-up length at 35℃:

$$S_{35} = P_{35}\frac{d_1}{K}\left(\frac{1}{E_2}\left(\frac{K_2^{\,2}+1}{K_2^{\,2}-1} + \mu_2\right) + \frac{1}{E_1}(1-\mu_1)\right) \qquad \text{mm}$$

Minimum pull-up length at temperature t ($t < 35$℃):

$$S_t = S_{35} + \frac{d_1}{K}(a_2 - a_1)(35 - t) \qquad \text{mm}$$

Corresponding minimum surface pressure at temperature t:

$$P_t = P_{35}\frac{S_t}{S_{35}} \qquad \text{N/mm}^2$$

Minimum push-up load at temperature t:

$$W_t = AP_t\left(\mu + \frac{K}{2}\right) \qquad \text{N}$$

Maximum permissible surface pressure at 0℃:

$$P_{max} = \frac{0.7R_{eH}(K_2^2-1)}{\sqrt{3K_2^4+1}} \quad \text{N/mm}^2$$

Maximum pull-up length at 0℃:

$$S_{max} = \frac{P_{max}}{P_{35}} S_{35} \quad \text{mm}$$

Maximum pull-up length at 35℃:

$$S_{max} = \frac{P_{max}}{P_{35}} S_{35} - \frac{35(\alpha_2-\alpha_1)d_1}{K} \quad \text{mm}$$

where: $B = \mu^2 - \frac{S_F^2 K^2}{4}$

$$F_v = \frac{2000CM_e}{d_1} \quad \text{N}$$

$$T = 1762\frac{N_e}{V} \quad \text{N}$$

S_F — factor of safety against friction slip at 35°C, not to be less than 2.8 under the action of rated torque (based on rated power r.p.m.) plus torque due to torsionals;

T — rated thrust, in N;

V — ship speed at rated horsepower, in kn;

μ — coefficient of friction between mating surfaces. For the oil injection method, the coefficient of friction is to be 0.13 for bosses made in copper-based alloy and steel;

F_v — shear force at interface, in N;

M_e — rated torque corresponding to N_e and n_e, in Nm;

C — constant:

C = 1 for turbines, geared diesel drives, electric drives and for direct diesel drives with a hydraulic or an electromagnetic or high elasticity coupling;

C = 1.2 for a direct diesel drive.

The c constant is increased if the shrinkage has to absorb an extreme high pulsating torque.

Maximum pull-up length at 35°C:

$$S_{max} = \frac{P_{max}}{P_{35}} S_{35} - 35(\alpha_2-\alpha_1)d_1/K \quad \text{mm}$$

where: K — taper of the propeller shaft cone, $K \leq 1/15$;

N_e — rated output transmitted to the propeller shaft, in kW;

n_e —propeller speed at rated output Ne, in r/min;

A —100% theoretical contact area of propeller boss and propeller shaft, in mm^2, as read from drawings and disregarding oil grooves;

$K_2 = \frac{d_2}{d_1}$

d_1 —diameter of propeller shaft at the midpoint of the taper in the axial direction, in mm;

d_2 — mean outer diameter of the propeller boss at the axial position corresponding to d_1, in mm;

μ_1 — Poisson's ratio for shaft material, see Table 11.4.5.2;

μ_2 — Poisson's ratio for propeller material l, see Table 11.4.5.2;

E_1 — modulus of elasticity of propeller shaft material, see Table 11.4.5.2;

E_2 — modulus of elasticity of propeller material, see Table 11.4.5.2;

t — temperature at time of fitting propeller on shaft, in°C;

α_1 — coefficient of linear expansion of propeller shaft material, see Table 11.4.5.2;

α_2 — coefficient of linear expansion of propeller material, see Table 11.4.5.2;

R_{eH} — yield point or 0.2% proof stress of propeller material, in N/mm^2.

Material factor Table 11.4.5.2

Material	Modulus of elasticity	Poisson's ratio	coefficient of linear expansion (1/℃)
Cast and forged steel	20.6×10^4	0.29	12×10^{-6}

Material	Modulus of elasticity	Poisson's ratio	coefficient of linear expansion (1/℃)
Cast iron	9.8×10^4	0.26	12×10^{-6}
Copper-based alloy Cu1 and Cu2	10.8×10^4	0.33	17.5×10^{-6}
Copper-based alloy Cu3 and Cu4	11.8×10^4	0.33	17.5×10^{-6}

11.4.5.3 Where keyless propellers are fitted by the oil shrink method at a temperature below 0℃, the ambient temperature for fitting the propeller to the shaft is not to be less than the value calculated by the following formula:

$$t_{\min} = \frac{KP_{\max}S_{35} - P_{35}KS_{35} - 35P_{35}d_1(\alpha_2 - \alpha_1)}{P_{35}d_1(\alpha_1 - \alpha_2)} \quad ℃$$

11.4.5.4 Prior to final pull-up, the contact area between the mating surfaces is to be checked and is not to be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable. After final pull-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

11.4.5.5 Prior to final pull-up, the propeller and shaft are to be at the same temperature and the mating surfaces are to be clean and free from oil or grease. The bedding of the propeller with the shaft is to be demonstrated in the workshop to the satisfaction of the Surveyor.

11.4.5.6 A copy of the fitting curve relative to temperature, and data of corresponding loads are to be kept on board. Special tools for fitting and dismantling purposes are also to be provided on board.

11.4.5.7 The formulae given in 11.4.5.2, for the ahead condition, will also give sufficient safety in the astern condition. The formulae are applicable for solid shafts only and are not applicable for propellers where a sleeve is introduced between shaft and boss.

CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

Section 1 GENERAL PROVISIONS

12.1.1 *General requirements*

12.1.1.1 The arrangement of shafting and the scantlings of shafts are, in addition to the provisions of Chapter 11 of this PART, to comply with the requirements of this Chapter. The whole shafting could only be finally approved after the previous approval of the torsional, axial and lateral vibrations as well as the alignment of the said shafting.

12.1.1.2 Calculations for vibration and alignment of shafting are to be submitted for approval. Reports on measurements as deemed necessary are to be submitted for approval or information.

12.1.1.3 Novel and sophisticated shafting may be approved provided that measurement reports for similar installations are available and proved to be in compliance with the provisions of this Chapter.

12.1.1.4 Where changes are subsequently made to a shafting which has been approved, e.g. by fitting a highly flexible coupling, changing the size of shaft bearings and the engine type, or fitting a gearbox or a propeller of a different design, or changing the number of bearings etc. revised calculations of shaft vibration and alignment are to be made as appropriate and submitted for approval.

12.1.1.5 Calculations of shaft vibration and alignment are to include the detailed specifications and documents necessary for approval and checking.

12.1.1.6 In addition to shafting alignment requirements in Section 5 of this Chapter, ships complying with the provisions of Appendix 1 of this Chapter may be assigned the notation ESA upon request.

12.1.2 *Restricted speed ranges*

12.1.2.1 Restricted speed ranges will be imposed in the regions of resonant speeds n_c, where amplitudes or stresses or torques resulting from shaft vibration exceed the limiting values for continuous running as specified in this Chapter. The engine is not to be run continuously in such restricted speed ranges.

12.1.2.2 The following speed range is to be avoided:

$$\frac{16n_c}{18-r} \sim \frac{(18-r)n_c}{16}$$

where: $r = n_c / n_e$, n_e being the rated speed (r/min).

12.1.2.3 The restricted speed range for continuous operation may be suitably extended where amplitudes or stresses or torques resulting from vibration approach the limiting values for transient running as specified in this Chapter, and may be adequately reduced where they marginally exceed the limiting value for continuous running.

12.1.2.4 Restricted speed ranges may also be ascertained by measurements, i.e. the range of speed to be avoided for continuous running may be taken as that over which the measured values of amplitudes, or stresses, or torques resulting from shaft vibration are in excess of those allowed for continuous running, having regard to the tachometer accuracy.

12.1.2.5 Where the torsional vibration causes hammering of transmission gears or where the pulsatory torque of the elastic elements exceeds the allowable value for continuous running, restricted speed ranges are also to be imposed.

12.1.2.6 Where restricted speed ranges are imposed, the tachometer accuracy is to be within ±2% in way of the restricted speed range.

12.1.2.7 Restricted speed ranges are to be marked red on the tachometer, and notice boards are to be fitted in front of the control stations.

12.1.3 *Measurements*

12.1.3.1 Manufacturers are required to carry out torsional and axial (if required) vibration measurements on benches to their products of a new design or having undergone a major alteration, and to have all the equivalent parameters checked.

12.1.3.2 ISC may decide whether measurements are required for verification, depending upon the conditions of the method of calculation, the magnitudes of amplitudes or stresses or torques contained in the calculations submitted. The vibration measurements may be dispensed with provided that measurement reports for similar installations are submitted and proved to be in compliance with the provisions of this Chapter.

12.1.3.3 The instrumentation, measured points and a series of revolution step of vibration measurements

are to be such that they can correctly demonstrate the characteristics of vibration mode to be measured.

Alternating torsional stresses are amplitudes of the maximum and minimum torsional stresses, which can be measured in relevant conditions of repetitive cycle process.

12.1.3.4 Where the difference between the measured and calculated values of natural vibration frequency is less than ±5%, the amplitudes or stresses (torque) at any cross-section of the system may be generally estimated by the measured amplitudes or stresses (torque) in accordance with the vibration mode under consideration.

12.1.3.5 The measurement reports of torsional vibration are to include order, angular amplitude or stress, natural frequency, torsional vibration of each shaft, vibratory torque of the gear and elastic couplings (where applicable) at each measuring point under test speed, and to make stress/torque and speed curves with the allowable value.

12.1.3.6 During measurement, the main engine is to start from the minimum steady speed to the rated speed, and the measurement is to be carried out under the condition of different speed and steady speed. Near the resonance speed, the speed separation is to be reduced appropriately.

12.1.3.7 In general, torsional vibration is to be measured in the following cases:

(1) the calculated torsional vibration stress has reached 70% of that permitted for continuous operation or over within the speed range of $r = 0.8$ to 1.0;

(2) the calculated torsional vibration stress is less than, but has reached 90% of that permitted for transient operation within the speed range of $r < 0.8$;

(3) certain novel shafting systems contain unconventional parts.

12.1.4 *Miscellaneous*

12.1.4.1 Where the bed-plates of machinery are installed on resilient mountings, the shafting is to be elastically connected.

12.1.4.2 The method of calculation and the particulars to be submitted in relation to the requirements of this Chapter may refer to ISC Guidelines for Vibration Control on Board Ships.

12.1.4.3 The pressure gauge and lower pressure alarm or amplitude monitoring device for oil supply are to be fitted for torsional or axial vibration dampers, for which the oil is supplied from the lubricating oil circulating system for main engine, unless effective measures are to be taken to identify the normal work of the vibration dampers.

12.1.4.4 The allowable stress of torsional vibration and allowable amplitude values of axial vibration may also be ascertained in accordance with Appendix 3, Chapter 9 of this PART.

Section 2 TORSIONAL VIBRATION

12.2.1 *Application*

12.2.1.1 The requirements of this Section are applicable to the following systems:

(1) main diesel engine propulsion systems, except in the case of ships classed for port service when fitted with engines having powers less than 110 kW.

(2) auxiliary diesel engine systems used for essential services, where the power developed by the auxiliary engines is 110 kW or over.

(3) propulsion systems formed by turbines;

(4) propulsion systems formed by electric motors.

12.2.2 *Torsional vibration calculations*

12.2.2.1 Torsional vibration calculation is to include: engine type, rated power, rated speed, shafting arrangement, tensile strength of shaft, equivalent parameters of torsional vibration for the dynamic system with necessary specification, Holzer tables for each vibration node under consideration and the associated vectorial sums of relative amplitudes, vibratory response calculation of main harmonics and the corresponding permissible values.

12.2.2.2 Where installations have different application conditions, e.g. combined with clutches, P.T.O. systems or having more than one engine, the torsional vibration calculations are to be carried out for each case.

12.2.2.3 Where there is considerable difference between the sizes of the spare propeller and the working propeller, torsional vibration is also to be calculated for the condition when the spare propeller is used.

12.2.2.4 The special speed requirements for prolonged periods in service are also to be indicated, e.g. the range of the service speed of a controllable pitch propeller and the range of the service speed of a P.T.O. system, etc.

12.2.2.5 Where controllable pitch propellers are fitted, torsional vibration calculations for zero and full

pitches are to be carried out.

12.2.2.6 Torsional vibration calculation is to be carried out with one cylinder misfiring in addition to that under normal working condition.

12.2.2.7 In general, the calculation is to cover the resonant conditions arising from all harmonic torque excitation up to order 12, in a speed range of 0.8 n_{min} to 1.2 n_e (n_{min} being the minimum steady speed, in r/min). For diesel engine propulsion system, if energy method is adopted to calculate torsional vibration, the calculation of non-resonant condition over 1.2 n_e, resulting from the main harmonic of one node vibration, is also to be carried out.

12.2.3 *Allowable stresses*

12.2.3.1 The allowable torsional vibration stresses for shafting are to be calculated based on the basic diameters of the shafts, i.e. the crankpin diameter for crankshafts, the minimum diameter for intermediate shafts and the minimum diameter between the aft bearing and the bulkhead gland for screwshafts, and the effect of the stress concentration on the plain sections of the shafting may be neglected.

12.2.3.2 The allowable torsional vibration stresses for main engine crankshafts are not to exceed the values given by the following formulae:

Continuous running ($0 < r \leq 1.0$):

$$[\tau_c] = \pm [(52-0.031d)-(33.8-0.02d)\, r^2] \quad N/mm^2$$

($1.0 < r \leq 1.05$):

$$[\tau_c] = \pm [(18.1-0.0113d)+(87.3-0.052d)\sqrt{r-1}\,] \quad N/mm^2$$

Transient running ($0 < r < 0.8$):

$$[\tau_t] = \pm 2.0\, [\tau_c] \quad N/mm^2$$

The symbols used in 12.2.3.2 to 12.2.3.4 are defined as follows:

$[\tau_c]$ — allowable torsional vibration stress for continuous running, in N/mm^2; $[\tau_t]$ — allowable torsional vibration stress for transient running, in N/mm^2;

d — basic diameter of shafts, in mm;

$r = n_c/n_e$;

n_c — critical speed, in r/min;

n_e — rated speed, in r/min.

12.2.3.3 High cycle fatigue criterion (typically >> 10^7), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The influence of reverse bending stresses is addressed by the safety margins, see the provisions of 11.2.2, Chapter 11 of this PART.

The allowable torsional vibration stresses for thrust, intermediate, tube shafts and screwshaft are not to exceed the values given by the following formulae:

Continuous running ($0 < r < 0.9$):

$$[\tau_c] = \pm C_W C_K C_D (3-2\, r^2) \quad N/mm^2;$$

($0.9 \leq r \leq 1.05$):

$$[\tau_c] = \pm 1.38\, C_W C_K C_D \quad N/mm^2;$$

Transient running ($0 < r \leq 0.8$):

$$[\tau_t] = 1.7\, [\tau_c] / \sqrt{C_K} \quad N/mm^2$$

where: C_W — material factor; $C_W = (R_m + 160)/18$;

R_m — specified tensile strength of shaft material, in N/mm^2. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 600 N/mm^2 for R_m> 600 N/mm^2; when alloy steel is used, it is to be taken as 800 N/mm^2 for R_m> 800 N/mm^2. For special approval of alloy steel used for intermediate shaft material, the tensile strength of shaft material may be greater than 800 N/mm^2, but less than 950 N/mm^2, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness ② and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of ISC Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm^2 for R_m> 600 N/mm^2;

C_K — shape coefficient, see Table 12.2.3.3;

C_D — size factor: $C_D = 0.35+0.93\, d^{-0.2}$. The size factor being a function of diameter only does not

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

Shape coefficient C_K *Table 12.2.3.3*

Intermediate shafts						Thrust shafts		Propeller shafts and tube shafts		
Integral coupling flange	Shrink fit coupling	Keyway, tapered connection	Keyway, cylindrical connection	Radial hole	Longitudinal slot	On both sides of thrust collar	In way of axial bearings where roller bearing is used as thrust bearing	Flange mounted or keyless taper fitted propeller shafts	Key fitted propeller shafts	The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead
1.0①	1.0①	0.6	0.45	0.50	0.30②	0.85	0.85	0.55	0.55	0.8

Notes: ① For multiple-arc transition intermediate shaft, if C_K is greater than 1, the testing basis or service experience is to be provided and approved by ISC.

② C_K = 0.3 is a safe approximation within the limitations in note 4 of Table 11.2.2.1. More accurate estimate of the shape coefficient C_K may be determined by direct application of FE calculation or the following formula. In which case:

$$C_K = \frac{1.45}{scf}$$

where: *scf* — stress concentration factor, which is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots), to be calculated according to following formula:

$$scf = 2.3 + 0.8 \times \frac{(l-e)/d}{\sqrt{(1-d_0/d)\times e/d}}$$

l — length of slot, in mm;
e — width of slot, in mm;
d — basic diameter of shaft, in mm;
d_0 — actual bore of shaft, in mm.
This formula applies to:
- slots at 120 or 180 or 360 degrees apart.
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$$\alpha_{t(hole)} = 2.3 - 3\times\frac{e}{d} + 15\times\left(\frac{e}{d}\right)^2 + 10\times\left(\frac{e}{d}\right)^2\times\left(\frac{d_i}{d}\right)^2$$

$\alpha_{t(hole)}$ represents the stress concentration of radial holes or simplified to 2.3.

12.2.3.4 The allowable torsional vibration stresses for the crankshafts and transmission shafts of diesel engines for generators and of auxiliary diesel engines for essential services and for the crankshafts of propulsion diesel engines running with constant speed are not to exceed the values given by the following formulae:

Continuous running $(0.9 \le r \le 1.10)$:

$$[\tau_c] = \pm (21.59 - 0.0132d) \quad N/mm^2;$$

Transient running $(0 < r < 0.95)$:

$$[\tau_t] = \pm 5.5\,[\tau_c] \quad N/mm^2.$$

12.2.3.5 For propulsion shafting running at constant speed, higher vibratory stress limits may be considered if background of service experience is provided.

12.2.3.6 Except the shafting material is of nodular graphite cast iron, the tensile strength of intermediate shaft material specified in 12.2.3.2 and 12.2.3.4 is greater than 430N/mm^2, the allowable stress τ' may be calculated by the following formula:

$$\tau' = \frac{R_m + 184}{614}\tau \quad N/mm^2$$

where: R_m — tensile strength of shaft material, in N/mm^2, to be taken as 600 N/mm^2 for R_m > 600 N/mm^2;

τ — allowable torsional vibration stress determined by 12.2.3.2 and 12.2.3.4 of this Section, in N/mm^2.

12.2.4 *Additional requirements for generators*

12.2.4.1 In the case of alternating current generators, the resultant vibration amplitudes at the rotor are not

to exceed 3.5 ° electrical degrees under rated load working conditions. Where the inverter provided with rectification can ensure the output of stable power supply to the grid for normal use, the electrical degree is not limited to 3.5° .

12.2.4.2 The vibratory inertia torques imposed on the generator rotors are to be limited to ± 2 M_e over the speed range of r = 0.95 to 1.10 (M_e being the torque at the rated speed), and to ± 6 M_e over the range of r < 0.95. Where a main engine drives two or more generators, the rated torque of each generator is to be taken into consideration separately.

12.2.5 *Allowable vibratory torques for gearing and flexible coupling*

12.2.5.1 The vibratory torque at gear engagement of the transmission gearing arrangements is not, in general, to exceed 1/3 of the rated full load mean torque in the range of r = 0.9 to 1.05. In cases where tooth surface contact stress and root bending stress of gears are less than the allowable values specified in Appendix 1, Chapter 10 of this PART, special consideration will be given to the acceptance of higher vibratory torque on the gears, but gear knock does not happen.

12.2.5.2 Flexible couplings are to be of such design that vibratory torque of the elastic elements is not to exceed the allowable pulsatory torque for continuous running and not to exceed the allowable pulsatory torque for transient running in the respective running conditions.

12.2.5.3 On the power output branch without load, the vibratory torque at gear engagement is not, in general, to exceed 20% of the rated full load mean torque.

12.2.6 *Miscellaneous*

12.2.6.1 No critical speed is to occur in the range of speed for normal service or in any special speed ranges required for service.

12.2.6.2 Restricted speed ranges in normal operating conditions (r = 0.8 to 1.0) are not acceptable. Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation.

12.2.6.3 The torsional vibration stresses caused by the upper flank at r = 0.8 are not to exceed the allowable stress [τ_c].

12.2.6.4 Resulted stresses arising from resonance and major non-resonance are not to exceed 1.5 times the allowable torsional vibration stresses limited by this Section in the range of r = 0.8 to 1.05.

12.2.6.5 Where data from experience or detailed calculations are furnished by manufacturers, allowable torsional vibration stresses (or torques) as supplied by the manufacturers may be adopted.

12.2.6.6 The allowable torsional vibration stresses for crankshafts may also be obtained in accordance with the Unified Requirements of IACS. However the calculations are to be submitted in accordance with the requirements of Appraisal of Crankshaft Strength of Diesel Engines in Appendix 3, Chapter 9 of this PART.

Section 3 AXIAL VIBRATION

12.3.1 *General requirements*

12.3.1.1 For all main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive axial vibration amplitudes throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for reducing the amplitudes are to be provided as appropriate.

12.3.1.2 Documents of axial vibration characteristics of the slow-speed two-stroke diesel engine direct propulsion shafting systems and of the turbine propulsion shafting systems are to be submitted for approval.

12.3.2 *Axial vibration calculations*

12.3.2.1 Axial vibration calculations are to include: engine type, rated power, rated speed, shafting arrangement, equivalent parameters of systems and the necessary specification, the Holzer tables of 0-node and 1-node vibration and the associated vectorial sums of relative amplitudes difference, the vibratory response of major harmonics and the associated limits.

12.3.3 *Allowable amplitudes*

12.3.3.1 For diesel engine propulsion shafting systems, axial vibration amplitudes for continuous running arising from axial vibration in the range of r=0 to 1.0 are not to exceed the values calculated by following formula:

$$[A_{a1}] = \frac{R[\Delta a_0]}{2(\Delta a_k)_{max}(R + \frac{d_j}{2})} \quad \text{mm}$$

where: $[A_{a1}]$ — allowable axial vibration amplitude for continuous running at the free-end of the crankshaft, in mm;

$(\Delta_{ak})_{max}$ — the maximum relative amplitude difference in the crankshaft of the axial vibration mode under consideration, in mm;

d_j — the main journal diameter of the crankshaft, in mm;

$[\Delta_{a0}]$ — the maximum allowable difference between crank webs, in mm;

R — radius of the crank, in mm.

12.3.3.2 Allowable axial vibration amplitudes for transient running are in general, to be 1.5 times those for continuous running.

12.3.3.3 Where allowable values for continuous running are exceeded, restricted speed ranges are to be imposed. Generally, axial vibration amplitudes caused by resonance or the upper flank at r = 0.85 are not to exceed the allowable values for continuous running, and those caused by resonance or the lower flank at r = 1.0 are not to exceed the allowable values for continuous running.

12.3.3.4 Where data from experience or detailed calculations are furnished by manufacturers, allowable axial vibration amplitudes as supplied by the manufacturers may be adopted.

Section 4 WHIRLING VIBRATION

12.4.1 *General requirements*

12.4.1.1 For main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive amplitudes due to whirling vibration throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for frequency modulation are to be provided as appropriate.

12.4.1.2 For the propulsion shafting systems with brackets and cardan shafts, details of the whirling vibration characteristics are to be submitted for approval.

12.4.2 *Whirling vibration calculations*

12.4.2.1 Whirling vibration calculations are to include: engine type, rated power, rated speed, speed ratio (where applicable), shafting arrangement, lengths and positions of bearings, bearing materials, propeller mass and inertia, the resonant speed of 1 order and blade orders forward and backward whirling vibrations.

12.4.2.2 During whirling vibration calculation, bearing stiffness are to be taken into account, and the load distribution on bearings is also to be considered.

12.4.3 *Speed ranges to be avoided*

12.4.3.1 For the shafting systems with brackets and cardan shafts, the blade order forward whirling resonant speeds are not to appear in the range of r = 0.85 to 1.0, and 1 order forward whirling resonant speeds are to be 20% more than the rated speed.

Section 5 SHAFTING ALIGNMENT

12.5.1 *General requirements*

12.5.1.1 The alignment of main propulsion shafting systems is to comply with the requirements of this Section. For shafting systems using environmentally acceptable lubricants, the alignment of shafting systems is to additionally comply with the requirements of Chapter 4 of the Guidelines for Surveys on Implementation of the Requirements of U.S. Environmental Protection Agency on Environmentally Acceptable Lubricants.

12.5.1.2 The alignment of main propulsion shafting systems and the arrangement of bearings are to be such as to give reasonable bending moments and bearing reactions and minimize the effects of hull deformation or bearing weardown on shafting alignment.

12.5.1.3 For the shafting alignment of large ships, the effects of hull deformation when the ship is ballasted or fully loaded are to be taken into consideration.

12.5.1.4 Shafting alignment calculations together with shafting instructions for the following main propulsion shafting systems are to be submitted for approval:
(1) shafting systems where the propeller shaft has a diameter (hereinafter referred to as propeller shaft diameter) of 250 mm or greater in way of the aftermost sterntube bearing;
(2) shafting systems fitted with no sterntube forward bearing where the propeller shaft diameter is 200 mm or greater;
(3) shafting systems with speed reduction gear, of which the wheel is driven by two or more than two pinions;
(4) shafting systems for which the sterntube bearings are to be slope-bored or inclined;
(5) shaft generator or electrical motor as an integral part of the low speed shaft in diesel engine propulsion.
12.5.1.5 Shafting alignment instructions are to correctly reflect the calculation results for the alignment in cold condition, containing at least the contents of 12.5.4 and 12.5.5 of this Section.
12.5.1.6 In respect to shafting systems where the propeller shaft diameter is less than 250 mm, shafting alignment calculations are in general to be submitted for reference.

Where shafting alignment calculations are not submitted, the span of bearings etc. are to be included in the shafting strength calculations required by subparagraph 11.1.4.1(4), Chapter 11 of this PART, referring to the relevant requirements for shafting alignment in Chapter 9 of ISC Guidelines for Shipboard Vibration Control. In addition, the technological documents submitted by the shipyard regarding shafting alignment are to contain alignment instructions.

12.5.2 *Shafting alignment calculations*

12.5.2.1 Shafting alignment calculation results are to comply with the requirements of 12.5.3.
12.5.2.2 For a propulsion shafting system directly driven by a diesel engine, shafting alignment calculations are generally to be performed up to the 1st main bearing at the free end of the engine. For a gear-driven shafting system, shafting alignment calculations are to be performed up to the fore end of the gear wheel.
12.5.2.3 In shafting alignment calculations, the influence of thermal expansion of heated bearings (e.g. 55℃) during operation of the engine or gearbox and so far as possible, the influence of expansion of heated tanks (e.g. 45℃) in double bottom that are located below intermediate shaft bearings, are to be taken into account.
12.5.2.4 In shafting alignment calculations, the influence of different ambient temperatures (taken as 0℃, 10℃ or 20℃) on the installation of shafting systems is to be taken into account so far as practicable.
12.5.2.5 Shafting alignment calculations are to include engine type, rated power, rated speed, shafting arrangement, all point loads and their acting positions, positions and lengths of bearings, allowable bending moments and shearing forces at the output flange of diesel engines, allowable loads of individual bearings, bearing clearances, relative slope between the propeller shaft and the aftermost sterntube bearing, gearbox information and allowable load difference between fore and aft bearings of the gear wheel.
12.5.2.6 The shaft deflection, the bending moments or stresses, shear forces, and angles at different shaft sections, the loads and reaction force influence numbers of bearings obtained during reasonable shafting alignment in both cold and hot conditions are to be submitted. For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the shaft deflection, relative angle and bearing loads at the zero rudder angle as a minimum under rated speed are to be provided, taking into account hydrodynamics of propellers. The calculation results are to comply with the requirements of 12.5.3.2 and 12.5.3.7.
12.5.2.7 A bearing load measurement procedure is to be submitted, covering actual measurements, jacking positions and jack correction factors.
12.5.2.8 The sag and gap values of each couple of flanges for the installation of shafting systems (shaft flanges being not connected) are to be provided.
12.5.2.9 For slope-bored sterntube bearings or bearing inclinations, a detailed description of slope bores or bearing inclinations is to be provided.

12.5.3 *Shafting alignment requirements*

12.5.3.1 In the static condition, all bearing loads are to be positive, i.e. there is to be no voidable bearing load. The bearing load is generally not to be less than 20% of the sum of all weights between two adjacent spans.
12.5.3.2 Bearing loads are in general not to exceed the values specified below or by the manufacturer:
aftermost sterntube bearings: as specified in 11.2.5.1, Chapter 11 of this PART;
sterntube forward bearings: 0.8 N/mm^2;
nonmetallic sterntube bearings: 0.3 N/mm^2;

intermediate shaft bearings: 0.8 N/mm^2;
gear shaft bearings: 1 N/mm^2;
main bearings of diesel engines: as specified by the engine manufacturer.

12.5.3.3 Additional bending stresses of shafts are generally not to exceed the following values:
propeller shafts and sterntube shafts: 20 N/mm^2;
intermediate shafts: 20 N/mm^2;
thrust shafts: 15 N/mm^2;
gear wheel shafts: 10 N/mm^2 or as specified by the gearbox manufacturer.

12.5.3.4 The bending moments and shearing forces applied to the output flange of diesel engines are not to exceed those as specified by the engine manufacturer (if required). The minimum load of main bearings of main engines is in general not to be less than 10% of the allowable load on main bearings. Alternatively, the minimum value specified by the engine manufacturer may be accepted, but this is to be reflected in shafting alignment calculations.

12.5.3.5 The load difference between fore and aft bearings of the gear wheel of the gearbox is to meet the relevant requirements of the manufacturer, generally not exceeding 20% of the sum of the weight of the shaft portion between the two bearings and that of the gear wheel.

Where the alignment calculation results in running condition are provided and the bearing structure is confirmed to be determined according to the acting angle of the resultant force in the running condition, the load difference between fore and aft bearings may not be limited to 20% as specified above provided that the relevant requirements of Appendix 1, Chapter 10 of this PART are complied with.

12.5.3.6 The relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition.

12.5.3.7 For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition and in the running condition considering hydrodynamics of propellers. Alternative recognized model technology may be accepted, e.g. multi-point support bearing model or fluid structure three dimensional FE model of interaction between bearing oil film and rotating shaft. Appropriate assumption and recognized modelling methods are to be indicated in the submitted report. The calculated oil film thickness in each analytical condition is not to be less than the minimum thickness value established for the oil film. Such criteria may replace aftermost bearing relative angle criteria.

12.5.4 *Conditions for shafting alignment*

12.5.4.1 The ship's superstructures, main engines, boilers, generators and other pieces of essential equipment are to have been hoisted to their respective places. There is to be no movement of essential equipment or change of ballasting during the alignment, installation and inspection on board.

12.5.4.2 The processing and welding of hull portions within shafting areas are to have been completed.

12.5.4.3 The temperatures of hull structures are to be stable and so far as practicable, uniform.

12.5.4.4 The installation of sterntube arrangements has been completed.

12.5.4.5 Where the ship is afloat, consideration is to be given to measures for preventing movement or rotation of the propeller shaft.

12.5.4.6 Where the ship is in a normal floating condition, the immersion of the propeller is to be so close as practicable to that indicated in calculations.

12.5.5 *Shafting alignment procedure*

12.5.5.1 Where the conditions specified in 12.5.4 are met, shafting alignment may be performed according to the approved alignment calculations or alignment technology (as specified in 12.5.1.4 or 12.5.1.6).

12.5.5.2 Where any noncompliance with calculation conditions (e.g. the ambient temperature, propeller immersion, ship's condition, load adjustment of main bearings of engines) may affect the alignment results during the installation of shafting systems, the alignment calculations together with alignment instructions are to be resubmitted for approval, unless such effects have been included in the calculations.

12.5.5.3 The shipyard is to give full consideration to the influence of deflection of boring equipment on the machining precision of stern tubes. After finishing machining of stern tubes, sizes of bores on stern tubes are to be measured to confirm the deviation of center lines of the stern tube body. Such deviation is to be taken into consideration during cylindrical grinding of stern bearing and compensation during machining is to be made for deviation from stern tube center line as appropriate.

12.5.5.4 After stern bearing is pressed and fitted, slope at stern bearing is to be measured. After the integrated stern tubes are poured and installed, slope at stern bearing is to be measured.

12.5.5.5 Where the load of the sterntube forward bearing is not positive for unconnected shafting flanges, the force applied downward from the propeller shaft forward flange is to comply with the calculations.

12.5.5.6 The axial distance of temporary supports, if fitted, is to comply with the calculations.

12.5.5.7 For shafting alignment, the propeller shaft forward flange is to be used as the reference for positioning bearings or temporary supports and the engine (or gearbox) from aft to fore by adjusting the sag and gap of unconnected flange pairs, in compliance with the relevant requirements.

12.5.5.8 The sag and gap tolerances of flange pairs for straight alignment shafting are to comply with the requirements of 12.5.6.1 and to be recorded.

12.5.5.9 The sag and gap values of flange pairs for the reasonable alignment shafting are to comply with the shafting alignment calculations and tolerances are to comply with the requirements of 12.5.6.1. After connection of flanges, at least a load verification is to be carried out on stern tube forward bearing (if any), intermediate bearing, last three bearings of the main engine (direct transmission propulsion system), wheel shaft bearing (if any) with the ship afloat, and tolerances are to comply with the requirements of 12.5.6.2 and appropriate records are to be made.

12.5.5.10 At the time of completing the shafting alignment, the gear engagement is to be examined or the difference between crank webs of engine measured, and the results are to comply with the requirements of 12.5.6.3 or 12.5.6.4 and appropriate records are to be made.

12.5.5.11 After completion of shafting alignment, coupling bolts are to be provided to flanges, chocks provided or epoxy resin cast to diesel engines (or gearboxes) and engine foundation bolts provided, followed by connection and fixing.

12.5.6 *Shaft alignment survey*

12.5.6.1 The sag and gap of flange pairs are to be examined, with tolerances generally not exceeding ±0.08 mm.

12.5.6.2 Where shafting alignment calculations are applied, actual bearing loads in cold condition may generally be measured by jacking up the loads. The jacking positions are to be the same as specified in calculations. Any deviation of measured loads from calculated ones is not to exceed 20% of the latter. For excessive tolerances, shafting alignment calculations may be carried out according to the measurement results which may be accepted where other requirements of 12.5.3 are still complied with. However, at least the loads of main bearings of the main engine are to be positive.

12.5.6.3 The gear engagement of gear-driven shafting systems is to be examined and the relevant requirements of the gearbox manufacturer are to be complied with.

12.5.6.4 For shafting systems directly driven by the diesel engine, the difference between crank webs of engine are to be examined and the relevant requirements of the engine manufacturer are to be complied with.

Appendix 1 ENHANCED SHAFT ALIGNMENT

1 *General Provisions*

1.1 Application

1.1.1 This Appendix applies to bearings which are white-metal lined and oil lubricated, and ships applying for enhanced shaft alignment (ESA) notation.

2 *Calculation Conditions*

2.1 When carrying out assessment of reasonable shafting alignment, the following calculation conditions are at least to be considered:

(1) ballast condition in both cold and hot conditions (empty tank and full tank are to be considered for aftpeak tank used as ballast tank); 3-5 (2) full load condition in both cold and hot conditions;

(3) ballast condition taking into account hydrodynamic propeller loads (zero rudder angle and full rudder angle under rated speed);

(4) full load condition taking into account hydrodynamic propeller loads (zero rudder angle and full rudder angle under rated speed).

3 *Hull Deflections*

3.1 Hull deflections are to be obtained by means of FE calculation or measurement data of similar ships (same type, similar ship size, similar double bottom height in engine room, similar sterntube and stern arrangement), and other recognized calculation methods.

3.2 Hull deflections in way of bearing position in the following conditions are to be provided:

(1) floating condition;

(2) ballast condition (empty tank and full tank are to be considered for aftpeak tank used as ballast tank);

(3) full load condition.

4 *Hydrodynamic Propeller Loads*

4.1 Hydrodynamic propeller loads may be obtained by means of calculation or empirical data.

4.2 In case the data of 4.1 is unavailable, hydrodynamic propeller loads may be selected in accordance with Table 4.2.

Hydrodynamic Propeller Loads *Table 4.2*

	Zero rudder angle	Full rudder angle
Single screw propulsion	-5% of Q +30% of Q	-30% of Q
Twin screw propulsion	+/-20% of Q	-40% of Q

Note: Q is rated torque;

Positive sign (+) implies upward bending moment;

Negative sign (-) implies downward bending moment.

5 *Aftermost Sterntube Bearing Contact Analysis*

5.1 The relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition and in the running condition considering hydrodynamics of propellers. Alternative recognized model technology may be accepted, e.g. multi-point support bearing model or fluid structure three dimensional FE model of interaction between bearing oil film and rotating shaft. Appropriate assumption and recognized modelling methods are to be indicated in the submitted report. The calculated oil film thickness in each analytical condition is not to be less than the minimum thickness value established for the oil film. Such criteria may replace aftermost bearing relative 3-6 angle criteria.

6 *Criteria*

6.1 The calculation results of calculation conditions (1) and (2) in paragraph 2 of this Appendix are to satisfy applicable requirements of 12.5.3.1 to 12.5.3.6 of this Chapter.

6.2 The bearing load calculation results of calculation conditions (3) and (4) in paragraph 2 of this Appendix are to satisfy applicable requirements of 12.5.3.2 of this Chapter, and there is to be no voidable bearing load. The aftermost bearing relative angle is to satisfy applicable requirements of paragraph 5 of this Appendix.

7 *Survey*

7.1 The bearing actual load in cold or hot ballast conditions (empty tank and full tank are to be considered for aftpeak tank used as ballast tank) corresponding to the calculations may be generally measured by means of jack-up tests. The jack-up position is to be the same as the calculations. The actual load is to comply with provisions for bearing loads in 12.5.3.2.

CHAPTER 13 STEERING GEAR AND WINDLASSES

Section 1 STEERING GEAR

13.1.1 *General requirements*

13.1.1.1 The requirements of this Section apply to steering gear of vessel.

13.1.1.2 The certificate requirements and product survey of steering gear are to comply with relevant requirements in Chapter 3, PART ONE of the Rules.

13.1.2 *Definitions*

13.1.2.1 For the purpose of this Section:

(1) **Main steering gear** is the machinery, rudder actuators, the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

(2) **Auxiliary steering gear** is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

(3) *Steering gear power unit is:*

① **in the case of electric steering gear**, an electric motor and its associated electrical equipment;

② **in the case of electro-hydraulic steering gear**, an electric motor and its associated electrical equipment and connected pump;

③ **in the case of other hydraulic steering gear**, a driving engine and connected pump.

(4) **Power actuating system** is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

(5) **Rudder actuator** is the component which converts directly hydraulic pressure into mechanical action to move the rudder.

(6) **Steering gear control system** is equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables. Steering gear control system also covers the equipment required to control the steering gear power actuating system.

(7) **Maximum ahead service speed** is the greatest speed which the ship is designed to maintain in service at sea at her deepest seagoing draught at maximum propeller RPM and corresponding engine MCR.

(8) **Maximum astern speed** is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest sea-going draught.

(9) **Maximum working pressure** is the maximum expected pressure in the system when steering gear is operated to comply with 13.1.5.2(1) of this Section.

(10) **Declared steering angle limits** are the operational limits in terms of maximum steering angle of propulsion and steering systems other than traditional arrangements for a ship's directional control (e.g. azimuth propulsion arrangements or water jet propulsion systems, but not limited to them), or equivalent, according to the manufacturer's guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the declared steering angle limits are to be declared by the directional control system manufacturer for each ship specific non-traditional steering means.

(11) **Hydraulic locking** are all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "bypass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

13.1.3 *Plans and documents*

13.1.3.1 The following plans and documents are to be submitted for approval:

(1) details of steering gear construction, including documents of strength calculations for principal component parts and materials selected etc.;

(2) steering gear hydrostatic power system, including documents of relief valve's setting and delivery capacity etc.;

(3) power supply system;

(4) control, monitoring alarm system.

13.1.4 *Materials*

13.1.4.1 All the steering gear components such as hydraulic cylinders, pressure housings of rotary vane type actuators, hydraulic power piping valves, flanges and fittings, and all components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other ductile material, duly tested in accordance with the requirements of ISC Rules for Materials and Welding. In general, such material is not to have an elongation of less than 12% nor a tensile strength in excess of 650 N/mm^2.

If reliable basis for use and relevant background information can be provided, grey cast iron may be accepted for redundant parts with low stress levels, excluding cylinders.

13.1.4.2 Where flexibility is required, approved hose assemblies are to be installed between two points where torsional deflection (twisting) is not subjected to under normal operating conditions. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

13.1.4.3 Hose assemblies are to be high pressure hydraulic hose fabricated according to the requirements of Chapter 2 of this PART and suitable for fluids, pressures, temperatures and relevant ambient conditions for which they intend.

13.1.4.4 Burst pressure of hoses is not to be less than four times the design pressure.

13.1.5 *Basic performance*

13.1.5.1 Unless the main steering gear is in compliance with 13.1.5.6 or 13.1.10.1, every ship is to be provided with a main steering gear and an auxiliary steering gear. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

13.1.5.2 The main steering gear and rudder stock is to be:

(1) of adequate strength and capable of putting the rudder over from 35° on one side to 35° the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and under the same conditions, from 35° either side to 30° the other side in not more than 28 s. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the main steering arrangements (equivalent to the main steering gear) are to be capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 2.3°/s with the ship running ahead at the maximum ahead service speed;

(2) operated by power where manual operation cannot meet the requirements above or in any case when, excluding strengthening for navigation in ice, a rudder stock is over 120 mm diameter in way of the tiller. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the main steering arrangements are to be operated by power;

(3) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

13.1.5.3 The auxiliary steering gear is to be:

(1) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

(2) capable of putting the rudder over from 15° one side to 15° the other side in not more than 60 s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the auxiliary steering arrangements (equivalent to the auxiliary steering gear) are to be capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0.5°/s; with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater;

(3) operated by power where manual operation cannot meet the requirements above or in any case when, excluding strengthening for navigation in ice, a rudder stock is over 230 mm diameter in way of the tiller. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, where the propulsion power exceeds 2,500 kW per thruster unit, the auxiliary steering arrangements are to be operated by power.

13.1.5.4 Manually operated gears are only acceptable when the operation does not require an effort exceeding 160 N and their constructions are to ensure that the hand wheels of the gears will not be damaged by counter-forces.

13.1.5.5 Main and auxiliary steering gear power units are to be:

(1) arranged to re-start automatically when power is restored after a power failure;

(2) capable of being brought into operation from a position in the navigation bridge;

(3) in the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given in the navigation bridge.

13.1.5.6 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that:
(1) in a passenger ship, the main steering gear is capable of operating the rudder as required in 13.1.5.2(1) of this Section while any one of the power units is out of operation;
(2) in a cargo ship, the main steering gear is capable of operating the rudder as required in 13.1.5.2(1) of this Section while operating with all power units;
(3) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained.
13.1.5.7 Steering gears, other than that of the hydraulic type, are to achieve the equivalent standards.
13.1.5.8 Steering gears are to be provided with positive rudder angle limiters. Power-operated steering gears are to be fitted with limit switches or similar devices, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control.
13.1.5.9 Effective means are to be fitted to the steering gear to keep the rudder steady.

13.1.6 *Construction and design*

13.1.6.1 Pressure cylinders of rudder actuators are to be designed in accordance with the relevant requirements of Chapter 6 of this PART for Class I pressure vessels, in addition to provisions of 13.1.10.3 and 13.1.10.4 of this Section. Accumulators, if fitted, are to comply with the relevant requirements of Chapter 6 of this PART.

13.1.6.2 Where the components subject to pressure are designed in accordance with the requirements of 13.1.6.1 of this Section, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R_m}{A} \text{ or } \frac{R_{eH}}{B}$$

whichever is less.

where: R_m — specified tensile strength of material at ambient temperature, in N/mm^2;
R_{eH} — specified yield stress or proof stress of the material at ambient temperature, in N/mm^2;
A and B — safety coefficient given by Table 13.1.6.2.

Safety coefficient A or B *Table 13.1.6.2*

Safety coefficient	Steel (except cast steel)	Cast steel	Nodular graphite cast iron
A	3.5	4	5
B	1.7	2	3

13.1.6.3 All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength. The welding details and welding procedures are to be subject to approval of ISC.
13.1.6.4 The construction of steering gear components is to be such as to minimize local concentrations of stress.
13.1.6.5 When determining the scantlings of piping and other steering gear components subjected to internal hydraulic pressure, the design pressure is to be at least equal to the greater of the following:
(1) 1.25 times the maximum working pressure;
(2) the relief valve setting.
13.1.6.6 All the steering gear components and the rudder stock are to be of sound and reliable construction. Any essential component which is not duplicated, where appropriate, is to use anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which are to be permanently lubricated or provided with lubrication fittings.
13.1.6.7 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.
13.1.6.8 Oil seals between non-moving parts forming part of the external pressure boundary are to be of the metal upon metal type or of an equivalent type.
Oil seals between moving parts forming part of the external pressure boundary are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.
13.1.6.9 Pipes, joints, valves, flanges and other fittings are to comply with the requirements for Class I piping in Chapter 2 of this PART. The design pressure is to be in accordance with 13.1.6.5.

13.1.6.10 For relevant requirements to rudder, rudder stock, tiller and quadrant, refer to Chapter 3, PART TWO of the Rules.

13.1.7 *Hydraulic system*

13.1.7.1 Pipes, joints, valves, flanges and other fittings in hydraulic piping of hydraulic power steering gear are to comply with the requirements for Class I piping in Chapter 2 of this PART. The design pressure is to be in accordance with 13.1.6.5.

13.1.7.2 Relief valves

(1) Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves is not to exceed the design pressure. The valves are to be of adequate nominal diameter and so arranged as to avoid an undue rise in pressure above the design pressure.

(2) Relief valves fitted as required in 13.1.7.2(1) are to comply with the following:

① the setting pressure is not to be less than 1.25 times the maximum working pressure;

② the minimum discharge capacity of the relief valve(s) is not to be less than 110% of the total capacity of the pumps which can deliver through it (them).

Under such conditions the rise in pressure is not to exceed 10% of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

13.1.7.3 Isolating valves

For rudder actuators with non-duplicated units, isolating valves are to be fitted at the connection of pipes to the hydraulic cylinders, and are to be directly fitted on the hydraulic cylinders.

13.1.7.4 Filters

Arrangements to maintain the cleanliness of the hydraulic fluid are to be provided taking into consideration the type and design of the hydraulic system.

13.1.7.5 Level alarm

A low level alarm is to be provided for the circulating oil tank of each hydraulic system to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms are to be given in the navigation bridge and in the machinery space where they can be readily observed.

13.1.7.6 Arrangements for bleeding air

Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

13.1.7.7 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

13.1.7.8 Storage tank

A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the circulating oil tank is to be provided, where the main steering gear is required to be power operated. The storage tank is to be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a content gauge.

13.1.7.9 Arrangement

The power piping for hydraulic steering gears is to be so arranged that transfer between units can be readily effected.

13.1.8 *Power supply and control systems*

13.1.8.1 Steering gear control is to be provided:

(1) for the main steering gear, both in the navigation bridge and in the steering gear compartment;

(2) where the main steering gear is arranged according to 13.1.5.6 of this Section, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not to be fitted, except in a tanker of 10,000 gross tonnage and upwards, a chemical carrier or a liquefied gas carrier;

(3) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it is also to be operable from the navigating bridge and is to be independent of the control system for the main steering gear.

13.1.8.2 Main and auxiliary steering gear control systems operable from the navigating bridge are to comply with the following:

(1) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.

(2) The system is to be capable of being brought into operation from a position in the navigation bridge.

13.1.8.3 The angular position of the rudder is to be:

(1) if the main steering gear is power operated, indicated in the navigation bridge. The rudder angle indication is to be independent of the steering gear control system;

(2) recognizable in the steering gear compartment.

13.1.8.4 Where applicable, following standard signboard is to be fitted at a suitable place on steering control position in the bridge or incorporated into operating instruction mentioned in 13.1.11.3 of this Section.

"Caution:

In Some Circumstances When Two Power Units Are Running Simultaneously the Rudder May Not Respond to Helm. If This Happens Stop Each Pump in Turn Until Control Is Regained."

The above signboard is related to steering gears provided with two identical power units intended for simultaneous operation, and normally provided with either their own control systems or two separate (partly or mutually) control systems which are/may be operated simultaneously.

13.1.8.5 Source of electrical power and cable installation

(1) Means for indicating that motors of electric and electrohydraulic steering gear are running is to be installed in the navigation bridge and at a suitable main machinery control position.

(2) Each electrical or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard, however, one of the circuits may be supplied through the emergency switchboard. Each power unit of electrical or electrohydraulic main steering gear complying with the requirements of 13.1.5.6 of this Section is to be served by one exclusive circuit fed directly from the main switchboard, and one of the afore-mentioned circuits may be fed from the emergency switchboard. An auxiliary electric or electrohydraulic steering gear associated with a main electrical or electrohydraulic steering gear may be connected to one of the circuits supplying this main steering gear. The circuits supplying an electrical or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

(3) When in a ship of less than 1,600 gross tonnage an auxiliary steering gear which is required in 13.1.5.3(3) of this Section to be operated by power is not electrically powered or is powered by an electrical motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

(4) Each main and auxiliary steering gear control system, if electrical and operable from the navigating bridge, is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment. Or alternatively, this control system may be supplied by a separate circuit directly from the same section of main or emergency switchboard bus-bars at a point on the switchboard adjacent to that supplying the said steering gear power circuit. For above-mentioned main and auxiliary steering gear, short circuit protection is only to be provided for power circuits of control system.

(5) The electrical power circuits and the steering gear control systems with their associated components, cables and pipes required in this Section are to be separated as far as practicable throughout their length.

13.1.8.6 Where the rudder stock is required to be over 230 mm diameter in way of the tiller (excluding strengthening for navigation in ice), or where the propulsion power exceeds 2,500 kW per thruster unit (applying to propulsion and steering systems other than traditional arrangements for a ship's directional control), an alternative power supply, sufficient at least to supply the steering gear power unit or the steering arrangements which complies with the requirements of 13.1.5.3(2) of this Section and also its associated control system and the rudder angle indicator, is to be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power is to be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

13.1.8.7 Where the alternative power source for steering gear is an independent engine driven hydraulic pump located in the steering gear compartment, automatic starting arrangements for the engine are to comply with the relevant requirements relating to the automatic starting arrangements of emergency generators.

13.1.9 *Monitoring and alarms*

13.1.9.1 The alarm and monitoring requirements for the steering gear are to be in accordance with Table 13.1.9.1 and comply with the relevant requirements of Section 4, Chapter 2, PART SEVEN of the Rules. The failures likely to cause uncontrolled movements of rudder as indicated in the Table below are to be clearly identified. In the event of detection of such failure, the rudder is to stop in the current position without manual intervention or is to return to the midship/neutral poistion. For mechanical failures such as

sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with the relevant requirements of 13.1.8.4 of this Section.

Alarm and Monitoring Requirements *Table 13.1.9.1*

No.	Item	Alarm and monitoring	Location	Note
1	Steering gear power unit	Power supply failure	Navigation bridge	–
2	Steering gear circuit and motor	Broken connections and overload	Navigation bridge and main control position in engine room	–
3	Steering gear motor	Indication of running		
4	Steering gear control system	Power supply failure	Navigation bridge	–
5		Earth fault on AC and DC circuits		If applicable (e.g. the control system is connected to main power supply through transformer)
6		Loop failures in closed loop systems (short circuit, broken connections and earth faults)		–
7		Data communication errors		If programmable electronic system is used
8		Computer hardware and software failures		
9		Deviation alarm		Deviation alarm is to be initiated if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures
10	Hydraulic oil tank of steering gear	Low level	Navigation bridge and machinery space	Each oil tank is to be monitored
11	Angular position of rudder	Rudder angle indication	Navigation bridge and steering gear compartment	See 13.1.8.3
12	Automatic rudder arrangement	Failure	Navigation bridge	—
13		Indication of operation		
14	Hydraulic oil	High temperature	Navigation bridge	If fitted with oil cooler
15	Hydraulic oil filter	High pressure difference	Navigation bridge	If oil filter is fitted
16	Steering gear (power or control) hydraulic system	Hydraulic locking	Navigation bridge	See 13.1.9.5

13.1.9.2 Short circuit protection and an overload alarm are to be provided for the circuits and motors referred to in 13.1.8.5(2) of this Section. Protection against excess current, including starting current, if provided, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents. Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter. Normal load is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions. Where a three-phase supply is used, an alarm is to be provided that will indicate failure of any one of the supply phases. The alarms required in this Article are to be both audible and visual and are to be situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled. Audible and visual alarms are also required to be provided in the navigation bridge.

13.1.9.3 For any main and auxiliary steering gear control system operable from the navigation bridge an audible and visual alarm is to be given in the navigation bridge in the event of failure of electrical power supply to the control system, or in the event of a power failure to any one of the steering gear power units.

13.1.9.4 When in a ship of less than 1,600 gross tonnage an auxiliary steering gear which is required in 13.1.5.3(3) of this Section is powered by an electrical motor primarily intended for other services, the requirements of 13.1.9.2 of this Section may be waived by ISC if satisfied with protection arrangement together with the requirements of 13.1.5.5

and 13.1.8.1(3) of this Section applicable to auxiliary steering gear.

13.1.9.5 Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided in the navigation bridge.

The alarm is to be activated whenever:

(1) position of the variable displacement pump control system does not correspond with given order; or

(2) incorrect position of 3-way full flow valve in constant delivery pump system is detected.

13.1.10 *Additional requirements*

13.1.10.1 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards, every other ship of 70,000 gross tonnage and upwards the main steering gear is to comprise two or more identical power units complying with the provisions of 13.1.5.6 of this Section.

13.1.10.2 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards, subject to the requirements specified in 13.1.10.3, the steering gear is to comply with the following requirements:

(1) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained within 45 s after the loss of one power actuating system.

(2) The main steering gear is to comprise either:

① two independent and separate power actuating systems, each capable of meeting the requirements of 13.1.5.2(1) of this Section; or

② at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 13.1.5.2(1) of this Section. Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems remain fully operational.

(3) Steering gears other than that of the hydraulic type are to achieve equivalent standards.

13.1.10.3 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards but of less than 100,000 tons deadweight, solutions other than those set out in 13.1.10.2 of this Section which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety standard is achieved and that:

(1) following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 s;

(2) where the steering gear includes only a single power actuator, stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance are to be submitted. See Appendix 1 to this Chapter for details.

13.1.10.4 Manufacturers of steering gear who intend their product to comply with the requirements of Appendix 1 of this Chapter are to submit corresponding information for approval by ISC.

13.1.11 *Arrangement*

13.1.11.1 In general, the steering gear is to be reliably secured to the seating with sufficient rigidity by fitting bolts or bolts and thrust plates.

13.1.11.2 The steering gear compartment is to be:

(1) readily accessible and, as far as practicable, separated from machinery spaces;

(2) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

13.1.11.3 Suitable operating instructions with a block diagram showing the change-over procedures for actuating systems and control systems of steering gear are to be permanently displayed in the navigation bridge and in the steering gear compartments.

13.1.11.4 A means of communication is to be provided between the navigation bridge and the steering gear compartment.

13.1.12 *Testing*

13.1.12.1 Testing at works

(1) The pipes, valves and other parts in hydraulic piping system of hydraulic power steering gear are to comply with the related requirements for class I piping in Chapter 2 of this PART.

(2) The pressure parts designed in accordance with 13.1.6.1 of this Section are to be tested in accordance

with the related requirements for class I pressure vessels in Chapter 6 of this PART.

(3) A hydraulic power unit pump is to be subject to a type test. The type test is to be carried out at workshop for a duration of not less than 100 h according to the following:

① the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure;

② during the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board;

③ during the whole test, no abnormal heating, excessive vibration or other irregularities are permitted;

④ after the test, the pump is to be disassembled and inspected.

Type test may be waived for a power unit which has been proven to be reliable in marine service.

(4) For a diesel engine of a hydraulic power unit, see Chapter 9 of this PART.

(5) For an electric motor of a hydraulic power unit, see Chapter 3, PART FOUR of the Rules.

(6) After testing of each part and completion of general installation, the steering gear is to be subject to the final inspection and operation test.

13.1.12.2 Testing on board

After installation on board the vessel, the hydraulic steering gear is to be subject to a hydraulic tightness test under 1.25 times the design pressure and any kind of steering gear is to be subject to and a running test in mooring condition.

13.1.12.3 Sea trials

The steering gear is to be tried out on sea trial in order to demonstrate satisfaction that the requirements of this Section have been met. The trial is to include the operation of the following:

(1) the steering gear, including demonstration of the performances required in 13.1.5.2(1) and 13.1.5.3(2). If the vessel cannot be tested at the deepest seagoing draught, steering gear trials are to be conducted at a displacement as close as reasonably possible to full-load displacement on either of the following conditions:

① where the rudder is fully submerged (zero speed waterline) and the vessel is in an acceptable trim condition; or

② where the rudder load and torque at the specified trial loading condition have been predicted and extrapolated to the full load condition.

In any case for the main steering gear trial, the speed of ship corresponding to the number of maximum continuous revolution of main engine could apply; for controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for the maximum continuous ahead R.P.M. at the main steering gear trial;

(2) the steering gear power units, including transfer between steering gear power units;

(3) the isolation of one power actuating system, checking the time for regaining steering capability;

(4) the hydraulic fluid recharging system;

(5) the emergency power supply required in 13.1.8.6 of this Section;

(6) the steering gear controls, including transfer of control and local control;

(7) the means of communication between the wheelhouse, engine room and the steering gear compartment;

(8) the alarms and indicators required in this Chapter;

(9) where steering gear is designed to avoid hydraulic locking this feature is to be demonstrated.

The trials in (2), (3), (4), (7), (8) and (9) above may be carried out during mooring trial.

Section 2 WINDLASSES

13.2.1 *General requirements*

13.2.1.1 The requirements of this Section apply to windlasses of vessel.

13.2.1.2 The certification requirements and product survey of windlasses are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.

13.2.1.3 The design, construction and testing of windlasses are to conform to a standard or code of practice accepted by ISC. To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing. The following are examples of standards recognized:

SNAME T & R Bulletin 3-15: 2018	Guide to the Design and Testing of Anchor Windlasses for Merchant Ships
ISO 7825: 2017	Deck machinery general requirements
ISO 4568: 2021	Shipbuilding - Sea-going vessels - Windlasses and anchor capstans

13.2.2 *Definitions*

13.2.2.1 For the purpose of this Section:

(1) **Working load** means the tension measured at wildcats, and is to be calculated in accordance with 13.2.5.2(1) of this Section.

(2) **Overload pull** means the capability of the windlass necessary to withstand an overload pull for a short time.

(3) **Mean speed** means the speed for raising two lengths of cable chains when three lengths of cable chains are in the water with the anchor hanged free.

(4) **Withstand load** means the maximum static load applied to chain cables which the windlass brake can withstand.

13.2.3 *Plans and documents*

13.2.3.1 The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted for approval:

(1) windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc.;

(2) dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation;

(3) hydraulic system, to include: piping diagram along with system design pressure; safety valves arrangement and settings; material specifications for pipes and equipment; typical pipe joints, as applicable; and technical data and details for hydraulic motors;

(4) electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable;

(5) control, monitoring and instrumentation arrangements;

(6) engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard;

(7) plans and data for windlass electric motors including associated gears rated 50 kW and over;

(8) calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the “load testing” including “overload” capacity of the entire windlass unit is not carried out at the shop (see 13.2.6.1).

13.2.3.2 The following plans and documents are to be submitted for information:

(1) windlass design specifications; anchor and chain cable particulars; anchorage depth; performance criteria; standard of compliance;

(2) operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

13.2.4 *Material and welding*

13.2.4.1 The materials for parts which are stressed by the pull of the chain when the cable lifer is disengaged (e.g. main shaft, driving gear, cable lifter, chain pulley, brake spindle, etc.) are generally to be made of steel. If chain cable passes through stopper, stopper is to be made of ductile material. Testing of material is to comply with the requirements of ISC Rules for Materials and Welding.

13.2.4.2 Materials used in the construction of torque-transmitting and load-bearing parts of windlasses and the testing of the materials are to comply with the requirements of ISC Rules for Materials and Welding. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers.

13.2.4.3 Weld joint designs are to be shown in the construction plans and are to be approved in association with the approval of the windlass design. Welding procedures and welders are to be qualified in accordance with the requirements of ISC Rules for Materials and Welding. Welding consumables are to be approved by ISC in the case they fall within the scope of ISC Rules for Materials and Welding; when they fall outside the scope of ISC Rules for Materials and Welding, they are to comply with national or international standards. The degree of non-destructive examination of welds and post-weld heat treatment, if any, are to be specified and submitted to ISC for consideration.

13.2.5 *Design and requirements*

13.2.5.1 Driving type

Windlasses are to be driven by prime movers or motors independent from other deck machinery. For hydraulic windlasses, the hydraulic pipes may be connected with the pipes for other deck machinery, provided that there is no interference to the operation of windlasses.

Where applicable, hand-operated windlasses may be accepted for ships having anchors of not more than 250 kg, and provision is to be made for prevention of injuring persons by handles.

13.2.5.2 Driving power

Windlasses are to be of sufficient power and are to be capable of working continuously, the working load and overload pull of which are to meet the following requirements:

(1) Windlasses are to be capable of working continuously for a period of 30 min at the mean speed as required in 13.2.6.3 of this Section. In general, stresses in each torque-transmitting component are not to exceed 40% of yield strength (or 0.2% proof stress) of the material under these loading conditions:

① where the design anchorage depth is less than or equal to 82.5 m:

$37.5\ d^2$, N for Class 1 stud link chains;

$42.5\ d^2$, N for Class 2 stud link chains;

$47.5\ d^2$, N for Class 3 stud link chains;

② where the design anchorage depth is greater than 82.5 m:

$37.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 1 stud link chains;

$42.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 2 stud link chains;

$47.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 3 stud link chains;

where: d — chain diameter, in mm;

D — design anchorage depth, in m.

The above working loads are based on the hoisting of one anchor at a time (for anchor weight, refer to the provisions of Section 2, Chapter 3, PART TWO of the Rules), and that the effects of buoyancy and the hawse pipes efficiency (assumed to be 70%) have been accounted for.

(2) Windlasses are to be capable of working continuously for a period of at least 2 min under an overload pull (without any requirements for hoisting speed) for breaking out the anchor. The overload pull is not less than 1.5 times the working load.

13.2.5.3 Other design loads

(1) Holding loads

Calculations are to be made to show that, in the holding condition (single anchor, cable lifter brake fully applied and chain cable lifter declutched), and under a load equal to 80% of the specified minimum breaking strength of the chain cable, the maximum stress in each load bearing component will not exceed yield strength (or 0.2% proof stress) of the material. For installations fitted with a chain cable stopper, 45% of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

(2) Inertia loads

The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

(3) Driving loads

Each transmission component is to be able to withstand the maximum output torque of the prime mover.

13.2.5.4 Reversing equipment

Power-operated windlasses are to be reversible.

13.2.5.5 Clutch

Windlasses are to be provided with a clutch located between the wildcat and driving shaft, and the clutches are to be provided with efficient locking devices. Hydraulically or electrically operated clutches are to be capable of being disengaged manually.

13.2.5.6 Brake

(1) Cable lifter brake

The wildcats or reels of windlasses are to be provided with efficient brakes to stop the anchor and chain cable when paying out the chain cable. The force-bearing parts of the brakes, when fully applied, are to withstand the following loads without permanent deformation and without brake slip.

① For windlasses fitted with a chain stopper, the brake is to be able to withstand a static pull equal to 45% of the breaking load of the cable or wire or the maximum static load of the cable or wire;

② For windlasses not fitted with a chain stopper, the brake is to be able to withstand a static pull equal to 80% of the breaking load of the cable or wire.

(2) Control brake

① Electric windlasses are to be provided with a fail-safe brake mechanism such that the brakes are automatically engaged when the operating device is in the stop or braking position, or when there is no power to the electric motors. The brake is to be able to function automatically and hold a load on the chain cable of 1.5 times the working load of the windlass.

② For other types of drives, a suitable fail-safe brake mechanism is to be used. The brake is to be able to hold a load on the chain cable of 1.3 times the working load of the windlass.

13.2.5.7 Chain cable stopper

Chain cable stopper, if fitted, along with its attachments is to be designed to withstand, without any permanent deformation, 80% of the specified minimum breaking strength of the chain cable.

13.2.5.8 Overload protection

Prime movers and transmission gears are to be provided with means for prevention of excessive moment and impact.

13.2.5.9 Protection of mechanical components

To protect mechanical parts including component housings, a suitable protection system is to be fitted to limit the speed and torque at the prime mover. Consideration is to be given to a means to contain debris consequent to a severe damage of the prime mover due to overspeed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

13.2.5.10 Hydraulic system

Hydraulic system of windlasses is also to comply with the relevant requirements of Section 7 of Chapter 2 and Section 7 of Chapter 4 of this PART.

13.2.5.11 Marking

Windlass is to be permanently marked with the following information:

(1) nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of Grade 3, with a holding load of 45 % of the breaking load of the chain cable);

(2) maximum anchorage depth, in metres.

13.2.5.12 For the strength requirements for anchors, chain cables and securing of windlasses, see the relevant requirements in Section 2, Chapter 3 of PART TWO of the Rules.

13.2.5.13 Electrical systems

(1) Electric motors are to meet the requirements in Section 2, Chapter 3 of PART FOUR of the Rules, and those rated 50 kW and over are to be certified. Motors exposed to weather are to have enclosures suitable for their location as provided for in the requirements in Table 1.3.2.2 of PART FOUR of the Rules. Where gears are fitted, they are to meet the requirements of ISO 6336-6 or other acceptable standards and those rated 100 kW and over are to be certified.

(2) Electric motors are to be protected in accordance with the requirements in 2.5.10 of PART FOUR of the Rules and cable sizing is to be in accordance with the requirements in Section 12, Chapter 2 of PART FOUR of the Rules. Electrical cables installed in locations subjected to the sea are to be provided with effective mechanical protection.

13.2.6 *Testing*

13.2.6.1 Testing at works

(1) The pumps, pipes, valves and fittings in piping system are to comply with the relevant requirements in Chapter 2 of this PART.

(2) For a diesel engine of a hydraulic power unit, see Chapter 9 of this PART.

(3) For an electric motor of a hydraulic power unit, see Chapter 3, PART FOUR of the Rules.

(4) After testing of each part and completion of general installation, the windlass is to be subject to final inspection and functional test to ensure that it complies with the design requirements in 13.2.5 above. Windlasses are to be inspected and witnessed by a Surveyor and include the following tests, as a minimum.

① No-load test

The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

② Load test

The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in 13.2.5.2 can be attained. For large windlass, where the manufacturing works does not have adequate facilities, load test (including the adjustment of the overload protection) can be carried out on board ship. In these cases, functional testing in the manufacturing works is to be performed under no-load conditions.

③ Brake capacity test.

The holding power of the cable lifter brake is to be verified either through testing or by calculation.

13.2.6.2 Testing on board

After installation on board the vessel, the hydraulic system of the windlass is to be subject to a hydraulic tightness test under 1.25 times the design pressure.

Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the cable lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake.

13.2.6.3 Sea trials

(1) In carrying out the trial of hoisting anchor by the windlass, a mean speed of hoisting one anchor from a depth of 82.5 m to a depth of 27.5 m is not to be less than 9 m/min (equivalent to hoisting two shots of chain cable). Where the depth of water in allowable trial areas is inadequate, the deepest sea area in allowable trial areas is to be selected for trial.

(2) Where the design anchorage depth is greater than 82.5 m, the windlass is also to be able to hoist one anchor from the design anchorage depth to a depth of 82.5 m at a mean speed not less than 3 m/min. Where the depth of waters for the anchoring test is not adequate for the design anchorage depth, consideration may be given to accepting an equivalent simulating test.

Appendix 1① GUIDELINES FOR THE ACCEPTANCE OF NON-DUPLICATED RUDDER ACTUATORS FOR TANKERS, CHEMICAL TANKERS AND GAS CARRIERS OF 10,000 GROSS TONNAGE AND UPWARDS BUT OF LESS THAN 100,000 TONS DEADWEIGHT

1.1 *Materials*

1.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder-stock are to be made of duly tested ductile materials complying with recognized standards. Materials for pressure retaining components are to be in accordance with recognized pressure vessel standards. These materials are not to have an elongation less than 12 per cent nor a tensile strength in excess of 650 N/mm^2.

1.2 *Design*

1.2.1 The design pressure should be assumed to be at least equal to the greater of the following:

(1) 1.25 times the maximum working pressure to be expected under the operating conditions required in 13.1.5.2(1);

(2) the relief valve(s) setting.

1.2.2 Analysis

In order to analyse the design, the following are required:

(1) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.

(2) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.

(3) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

1.2.3 Allowable stresses

For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$$\sigma_m \le f$$
$$\sigma_l \le 1.5f$$
$$\sigma_n \le 1.5f$$
$$\sigma_l + \sigma_n \le 1.5f$$
$$\sigma_m + \sigma_n \le 1.5f$$

where: σ_m — equivalent primary general membrane stress, in N/mm^2;

σ_l — equivalent primary local membrane stress, in N/mm^2;

σ_n — equivalent primary bending stress, in N/mm^2;

f = the lesser of R_m/A or R_{eH}/B;

R_m — specified minimum tensile strength of material at ambient temperature, in N/mm^2;

R_{eH} — specified minimum yield stress or proof stress of material at ambient temperature, in N/mm^2.

A and B are listed in Table 1.2.3.

Table 1.2.3

Numerical value	Forged steel	Cast steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

1.2.4 Burst test

(1) Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required in 1.2.2(2) need not be provided.

(2) The minimum bursting pressure is to be calculated as follows:

---

① This Appendix is from the Annex to IMO resolution A.467(XII).

$$P_b = PA(R_{ma}/R_m) \quad \text{MPa}$$

where: P_b — minimum bursting pressure, in MPa;
P — design pressure as defined in 1.2.1, in MPa;
A — selected from Table 1.2.3;
R_{ma} — actual tensile strength, in N/mm^2;
R_m — tensile strength as defined in.1.2.3, in N/mm^2.

1.3 *Construction details*

1.3.1 The construction is to be such as to minimize local concentrations of stress.

1.3.2 The welding details and welding procedures are to be approved.

1.3.3 All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be full penetration type or of equivalent strength.

1.3.4 Oil seals forming part of the external pressure boundary are to comply with 13.1.6.8 of this Chapter.

1.3.5 Isolating valves are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

1.3.6 Relief valves for protecting the rudder actuator against over-pressure as required in 13.1.7.2 of this Chapter are to comply with the following:

(1) The setting pressure is not to be less than 1.25 times the maximum working pressure expected under operating conditions required in 13.1.5.2(1) of this Chapter.

(2) The minimum discharge capacity of the relief valve(s) is not to be less than 110% of the total capacity of all pumps which provided power for the actuator. Under such conditions the rise in pressure should not exceed 10% of the setting pressure. In this regard due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

1.4 *Non-destructive testing*

1.4.1 The rudder actuator should be subject to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws.

1.4.2 The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognized standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

1.5 *Testing*

1.5.1 Tests, including hydrostatic tests, of all pressure parts at 1.5 times the design pressure should be carried out.

1.5.2 When installed on board the ship, the rudder actuator should be subject to a hydrostatic test and a running test.

CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

14.1.1 *General requirements*

14.1.1.1 For ships with ice notations B1*, B1, B2, B3, the machinery installations are to additionally comply with the provisions of this Chapter. For ships with ice notation B, only the requirements of 14.1.1.2 and 14.1.1.4 need to be complied with.

14.1.1.2 For ships with ice notations B1*, B1, B2, B3 and B, the machinery installations are to be capable of assuring safe and normal operation under air temperatures below 0℃. Particular attention is to be paid to the functioning of hydraulic systems, anti-freezing of water piping and tanks, starting of emergency diesels at low temperatures.

14.1.1.3 The strengthening requirements for ice notations B1*, B1, B2 and B3 correspond respectively to the relevant provisions in the Finish-Swedish Ice Class Rules, 2021, as follows:

B1* — IA Super;
B1 — IA;
B2 — IB;
B3 — IC.

14.1.1.4 In addition to complying with the requirements of 14.1.1.2, ships with ice notation B are to be designed to ensure supply of cooling water when navigating in ice. For this purpose, at least one cooling water inlet chest is to be so arranged as to prevent its grating and sea suction from being blocked by brash ice.

14.1.1.5 In addition to the plans and documents required in other Chapters of this PART, for ships with ice notations B1*, B1, B2 and B3, main engine output calculations (including necessary diagrams) are to be submitted for approval.

14.1.2 *Main engine output*

14.1.2.1 The main engine output mentioned in this Chapter is the total maximum output the propulsion machinery can continuously deliver to propeller(s).

14.1.2.2 The main engine output is to be in no case less than 2,800 kW for Ice Class B1* and less than 1,000 kW for Ice Classes B1, B2 and B3.

14.1.2.3 For ships with ice notations B1*, B1, B2 and B3, the required main engine output N_r is to be determined by the following formula. The engine output requirement is to be calculated for two draughts. Draughts to be used are the maximum draught amidships referred to as UIWL and the minimum draught referred to as LIWL, as defined in 4.1.2 of PART TWO of the Rules. In the calculations, the ship's parameters which depend on the draught are to be determined at the appropriate draught, but *L* and *B* are to be determined only at the UIWL. The main engine output is not to be less than the greater of these two outputs.

$$N_r = K_e \frac{\left(\frac{R_{CH}}{1000}\right)^{3/2}}{D_p} \quad \text{kW}$$

where: D_p — diameter of the propeller, in m;

K_e — propulsion coefficient, for conventional propulsion systems, to be taken from Table 14.1.2.3(1), for advanced propulsion systems, to be determined by ship model tests and other equivalent methods, but the requirements of 14.1.2.4 are to be complied with.

Propulsion Coefficient K_e *Table 14.1.2.3(1)*

Propeller type or machinery	CP or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

R_{CH} — the resistance of the ship in a channel with brash ice and a consolidated layer, in N, to be determined by the following formula:

$$R_{CH} = C_1 + C_2 + 845 C_\mu \left(H_F + H_M\right)^2 \left(B + C_\psi H_F\right) + 42 L_{PAR} H_F^2 + 825 \left(\frac{LT}{B^2}\right)^3 \frac{A_{wf}}{L}$$

where C_1 and C_2 are coefficients taking into account a consolidated upper layer of the brash ice and taken as zero for B1, B2 and B3; for B1*:

$$C_1 = 23\frac{BL_{PAR}}{\frac{2T}{B}+1} + (1+0.021\varphi_1)(45.8B + 14.7L_{BOW} + 29BL_{BOW});$$

$$C_2 = (1+0.063\varphi_1)(1530+170B) + (400+480\frac{T}{B})\frac{B^2}{\sqrt{L}};$$

$$C_\mu = 0.15\cos\varphi_2 + \sin\psi\sin\alpha, \quad C_\mu \geq 0.45;$$

$$C_\psi = 0.047\psi - 2.115, \text{ and } C_\psi = 0 \text{ if } \psi \leq 45°;$$

$$\left(\frac{LT}{B^2}\right)^3 \text{ is not to be greater than 20 or less than 5;}$$

$$\psi = \arctan\left(\frac{\tan\varphi_2}{\sin\alpha}\right);$$

A_{wf} — area of waterline of the bow, in m^2, see Figure 14.1.2.3;

B — maximum breadth of the ship, measured horizontally from outside of frame to outside of frame, in m;

H_M — thickness of the brash ice in mid channel, in m, to be taken as 1.0 for B1* and B1, 0.8 for B2 and 0.6 for B3;

H_F — thickness of the brash ice layer displaced by the bow, in m, $H_F = 0.26 + \sqrt{H_M B}$;

L_{BOW} — length of the bow, in m, see Figure14.1.2.3;

L_{PAR} — length of the parallel midship body, in m, see Figure 14.1.2.3;

L — length of the ship between the perpendiculars, in m, measured from the forward side of the stem to the after side of the rudder post, or to the center of the rudder stock if there is no rudder post;

T — actual ice class draughts of the ship, i.e. maximum draught amidships referred to as UIWL and the minimum draught referred to as LIWL, in m;

α — the angle of the waterline at B/4, in °, see Figure 14.1.2.3;

φ_1 — the rake of the stem at the centerline, in °, see Figure 14.1.2.3, for bulbous bow, φ_1 = 90°;

φ_2 — the rake of the bow at B/4, in °, see Figure 14.1.2.3.

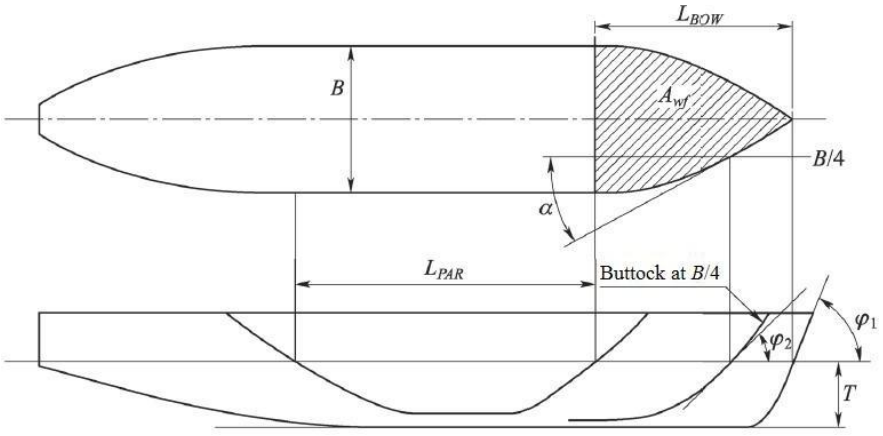


Figure 14.1.2.3

14.1.2.4 Where the value of K_e or R_{CH} is determined by ship model tests and other equivalent methods, the design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

B1* H_M = 1.0 m and a 0.1 m thick consolidated layer of ice;

B1 H_M = 1.0 m;

B2 H_M = 0.8 m;

B3 H_M = 0.6 m.

Section 2 PROPULSION MACHINERY

14.2.1 *General requirements*

14.2.1.1 These requirements apply to propulsion machinery, including controllable pitch (CP) or fixed pitch (FP) propellers and ducted-type propellers.The loads given are the expected ice loads for the ship's entire service life under normal operational conditions, including loads resulting from the changing rotational direction of fixed pitch propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

14.2.1.2 These requirements also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction and loads on the thruster body/ice interaction. The given loads are the expected ice loads for the ship's entire service life under normal operational conditions. However, the load models do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially). The local strength of the thruster body is to be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads. The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

14.2.1.3 The given loads are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the ship. Thus, the load level for a higher number of loads is lower.

14.2.1.4 If the highest point of the propeller is not at a depth of at least h_0 as specified in Table 4.2.4.2(1), Chapter 4, PART TWO of the Rules below the water surface when the ship is in ballast condition, the propulsion system is to be designed according to ice class B1 for ice classes B2 and B3.

14.2.2 *Definitions of parameter symbols and loads*

14.2.2.1 The main symbols, designations and units used for parameters in this Section are defined as follows:

c — chord length, in m, of blade section;
$c_{0.7}$ — chord length, in m, of blade section at 0.7 R propeller radius;
D — propeller diameter, in m;
d — external diameter, in m, of propeller hub;
D_{limit} — limit value, in m, for propeller diameter;
EAR — expanded blade area ratio;
F_b — maximum backward blade force, in kN, for the ship's service life;
F_{ex} — ultimate blade load, in kN, resulting from blade loss through plastic bending, referred to as blade failure load for short;
F_f — maximum forward blade force, in kN, for the ship's service life;
F_{ice} — ice load, in kN;
$(F_{\text{ice}})_{\max}$ — maximum ice load, in kN, for the ship's service life;
h_0 — depth, in m, of the propeller centreline from lower ice waterline;
H_{ice} — thickness, in m, of maximum design ice block entering into propeller;
I — equivalent mass moment, in kgm^2, of inertia of all parts on engine side of component under consideration;
I_t — equivalent mass moment, in kgm^2, of inertia of the whole propulsion system;
k — shape parameter for Weibull distribution;
LIWL — lower ice waterline, in m;
m — slope for S-N curve in log/log scale;
M_{BL} — blade bending moment, in kN·m;
n — propeller rotational speed, in r/s;
n_n — nominal propeller rotational speed, in r/s, at maximum continuous rating (MCR) in free running condition;
N_{class} — reference number of impacts per propeller rotational speed per ice class;
N_{ice} — total number of ice loads on propeller blade for the ship's service life;
N_R — reference number of load for equivalent fatigue stress (10^8 cycles);
N_Q — number of propeller revolutions during a milling sequence;
$P_{0.7}$ — propeller pitch, in m, at 0.7 R radius;
$P_{0.7n}$ — propeller pitch, in m, at 0.7 R radius at MCR in free running condition;
$P_{0.7b}$ — propeller pitch, in m, at 0.7 R radius at MCR in bollard condition;
Q — torque, in kN·m;

Q_{emax} — maximum engine torque, in kN·m;
Q_{max} — maximum torque, in kN·m, on the propeller resulting from propeller-ice interaction;
Q_{max}^{n} — maximum torque, in kNm, on the propeller resulting from propeller/ice interaction reduced to the rotational speed in question;
Q_{motor} — electric motor peak torque, in kN·m;
Q_n — nominal torque, in kN·m, at MCR in free running condition;
Q_r — maximum response torque, in kN·m, along the propeller shaft line;
Q_{peak} — maximum of the response torque Q_r, in kNm;
Q_{smax} — maximum spindle torque, in kN·m, of the blade for the ship's service life;
Q_{sex} — maximum spindle torque due to blade failure caused by plastic bending F_{ex}, in kNm;
Q_{vib} — vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC) , in kNm;
R — propeller radius, in m;
r — blade section radius, in m;
T — propeller thrust, in kN;
T_b — maximum backward propeller ice thrust, in kN, for the ship's service life;
T_f — maximum forward propeller ice thrust, in kN, for the ship's service life;
T_n — propeller thrust, in kN, at MCR in free running condition;
T_r — maximum response thrust, in kN, along the shaft line;
t — maximum blade section thickness, in m;
Z — number of propeller blades;
α_i — duration of propeller blade/ice interaction expressed in rotation angle, in degrees;
a_1 — phase angle of propeller ice torque for blade order excitation component, in degrees;
a_2 — phase angle of propeller ice torque for twice the blade order excitation component, in degrees;
$\gamma_{\varepsilon 1}$ — the reduction factor for fatigue (scatter effect);
$\gamma_{\varepsilon 2}$ — the reduction factor for fatigue (test specimen size effect);
γ_v — the reduction factor for fatigue (variable amplitude loading effect);
γ_m — the reduction factor for fatigue (mean stress effect);
ρ — a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles;
$\sigma_{0.2}$ — proof yield strength, in MPa, of blade material;
σ_{exp} — mean fatigue strength, in MPa, of blade material at 10^8 cycles to failure in seawater;
σ_{fat} — equivalent fatigue ice load stress amplitude, in MPa, for 10^8 stress cycles;
σ_{fl} — characteristic fatigue strength, in MPa, for blade material;
σ_{ref} — reference stress, in MPa, $\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$;
σ_{ref2} — reference stress, in MPa, $\sigma_{ref2} = 0.7 \cdot \sigma_u$ or $\sigma_{ref2} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$, whichever is less;
σ_{st} — maximum stress, in MPa, resulting from F_b or F_f;
σ_u — ultimate tensile strength, in MPa, of blade material;
$(\sigma_{ice})_{bmax}$ — principal stress, in MPa, caused by the maximum backward propeller ice load;
$(\sigma_{ice})_{fmax}$ — principal stress, in MPa, caused by the maximum forward propeller ice load;
$(\sigma_{ice})_{max}$ — maximum ice load stress amplitude, in MPa.

14.2.2.2 The definitions and uses of loads used in these requirements are given in Table 14.2.2.2.

Definitions and Uses of Loads *Table 14.2.2.2*

Load	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7 R chord line. See Figure 14.2.2.2. Ice contact pressure at the leading edge is shown with small arrows	Design force for strength calculation of the propeller blade
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7 R chord line	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade	In designing the propeller strength, the spindle torque is taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area

Load	Definition	Use of the load in design process
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust	Used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in these requirements
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust	Used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in these requirements
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade	Used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force may cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8 *R*. Spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and the leading/trailing edge (whichever is the greater) at the 0.8 *R* radius	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and thrust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller	Design torque for propeller shaft line components
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller	Design thrust for propeller shaft line components
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub	Design load for thruster body and slewing bearings
F_{tr}	Maximum response force on the thruster body caused by ice ridge/thruster body interaction.	Design load for thruster body and slewing bearings

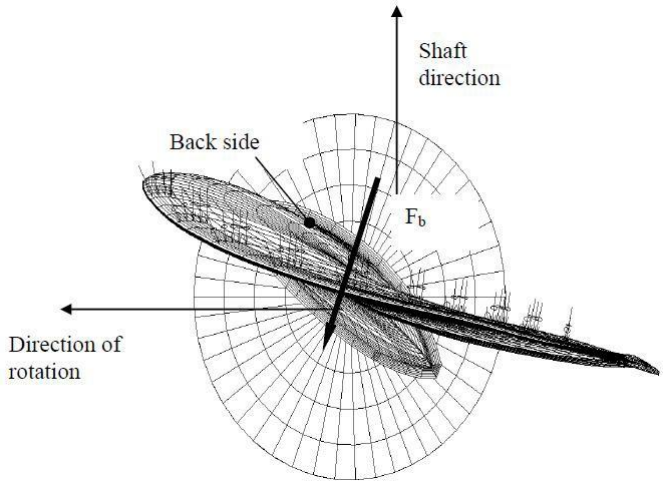


Figure 14.2.2.2 Direction of the backward blade force

14.2.3 Design ice conditions

14.2.3.1 In estimating the ice loads of the propeller for ice classes, different types of operation as given in Table 14.2.3.1 were taken into account.

Types of Operation for Ice Classes *Table 14.2.3.1*

Ice class	Operation of the ship
B1*	The ship may proceed by ramming for operation in ice channels and in level ice (not requiring ice breaker assistance)
B1, B2, B3	Operation in ice channels (if necessary, with ice breaker assistance)

14.2.3.2 For the estimation of design ice loads, a maximum ice block size is first to be determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \times 2\ H_{ice} \times 3\ H_{ice}$. The design thickness of the ice block (H_{ice}) is given in Table 14.2.3.2.

Design Ice Thickness *Table 14.2.3.2*

Ice class	B1*	B1	B2	B3
Thickness of the design maximum ice block entering the propeller (H_{ice})	1.75 m	1.5 m	1.2 m	1.0 m

14.2.4 Materials

14.2.4.1 Materials exposed to seawater

Materials of components exposed to seawater, such as propeller blades, propeller hubs, and thruster body, are to have an elongation of not less than 15% on a test specimen, the gauge length of which is five times the diameter. A Charpy-V impact test is to be carried out for materials other than bronze and austenitic stainless steel. An average impact energy value of not less than 20 J taken from three tests is to be obtained at minus 10℃. For nodular cast iron, average impact energy of 10 J at minus 10 ℃ is required accordingly.

14.2.4.2 Materials exposed to seawater temperature

Materials exposed to seawater temperature are to be of ductile material. An average impact energy value of not less than 20 J taken from three tests is to be obtained at minus 10℃. This requirement applies to the propeller shaft, blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to surface hardened components, such as bearings and gear teeth. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron is to be a minimum of 10 J at minus 10 ℃.

14.2.5 *Design loads*

14.2.5.1 Design loads on propeller blades

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead. These forces originate from different propeller/ice interaction phenomena, not acting simultaneously. Hence they are to be applied to one blade separately.

(1) Maximum backward blade force F_b for propellers

For $D \le D_{\text{limit}}$

$$F_b = 27(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \quad \text{kN}$$

For $D > D_{\text{limit}}$

$$F_b = 23(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} DH_{ice}^{1.4} \quad \text{kN}$$

where: $D_{\text{limit}} = 0.85H_{ice}^{1.4}$, in m;

n — the nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

(2) Maximum forward blade force F_f for propellers

For $D \le D_{\text{limit}}$

$$F_f = 250\frac{EAR}{Z}D^2 \quad \text{kN}$$

For $D > D_{\text{limit}}$

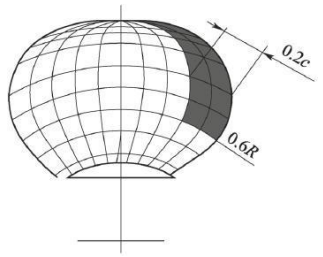
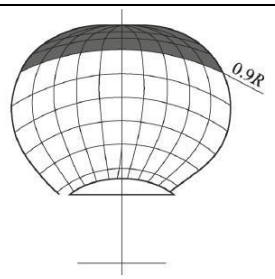
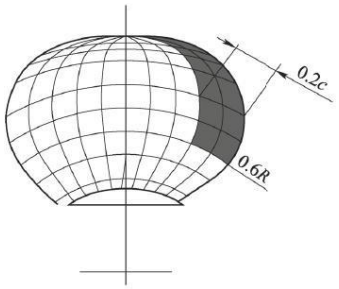
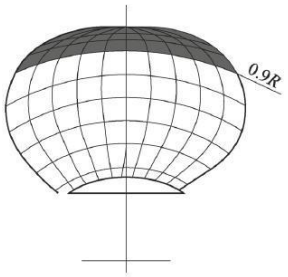
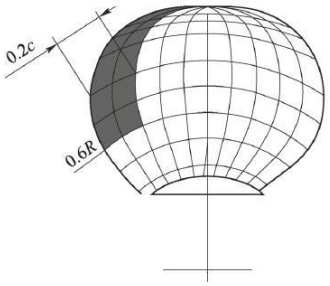
$$F_f = 500\frac{EAR}{Z}D\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice} \quad \text{kN}$$

where: $D_{limit} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m.

(3) Loaded area on the blade for propellers

Load cases 1 ~ 4 are to be covered, as given in Table 14.2.5.1(3), for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 is also to be covered for FP propellers.

Load Cases for Propellers *Table 14.2.5.1(3)*

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50%F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9 R radius	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 4	50%F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9 R radius	
Load case 5	60%F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

(4) Maximum backward blade ice force F_b for ducted propellers

For $D \leq D_{limit}$

$$F_b = 9.5(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \qquad \text{kN}$$

For $D > D_{limit}$

$$F_b = 66\,(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^{0.6} H_{ice}^{1.4} \quad \text{kN}$$

where: $D_{limit} = 4\,H_{ice}$, in m;

n — the nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

(5) Maximum forward blade ice force F_f for ducted propellers

For $D \le D_{limit}$

$$F_f = 250\frac{EAR}{Z}D^2 \quad \text{kN}$$

For $D > D_{limit}$

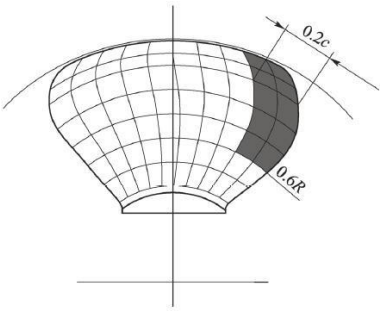
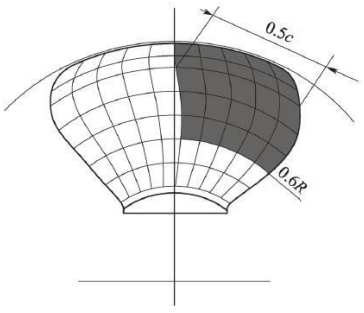
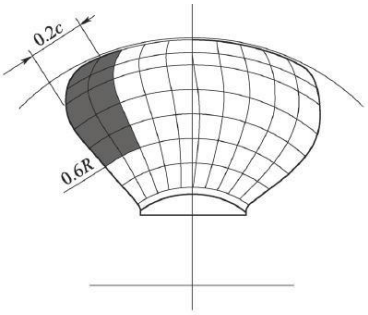
$$F_f = 500\frac{EAR}{Z}D\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice} \quad \text{kN}$$

where: $D_{limit} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m.

(6) Loaded area on the blade for ducted propellers

Load cases 1 and 3 are to be covered as given in Table 14.2.5.1(6) for all propellers, and load case 5 is to be additionally covered for an FP propeller to reflect ice loads when the propeller is reversed.

Load Cases for Ducted Propellers *Table 14.2.5.1(6)*

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 5	60%F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

(7) Maximum blade spindle torque for open and ducted propellers

The spindle torque around the axis of the blade fitting is to be calculated both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in Table 14.2.5.1(3) and Table 14.2.5.1(6). The larger of the obtained torques is used as the dimensioning torque. If the above method gives a value which is less than the

$$Q_{smax} = 0.25 F c_{0.7} \quad \text{kN·m}$$

default value given by the formula below, the default value is to be used.

where: F — F_b or F_f, whichever is greater.

(8) Load distributions for blade loads

The Weibull distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Figure 14.2.5.2(8), is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \geq \frac{F}{(F_{ice})_{max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{max}}\right)^{k} \ln(N_{ice})\right)}$$

where: k — shape parameter of the spectrum, k = 0.75 for an open propeller and k = 1.0 for a ducted propeller;

N_{ice} — number of load cycles in the spectrum;

F_{ice} — random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

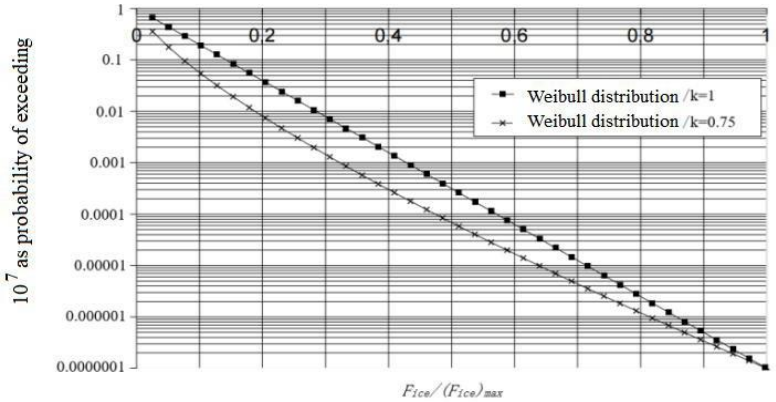


Figure 14.2.5.1(8) Weibull distribution (probability of exceeding) used for fatigue design

(9) Number of ice load cycles

The number of load cycles per propeller blade in the load spectrum is to be determined according to the following formula:

$$N_{ice} = k_1 k_2 k_3 N_{class} n_n$$

where: N_{class}— reference number of impacts per propeller rotational speed for ice classes, taken from Table 14.2.5.1(9);

k_1 — propeller location factor, k_1 = 1 for centre propellers bow first operation, k_1 = 2 for wing propellers bow first operation and k_1 = 3 for pulling propeller (wing and centre) bow propeller or stern first operation;

k_2 — submersion factor, determined as follows:

$k_4 = 0.8 - f$ for $f < 0$;

$k_4 = 0.8 - 0.4 f$ for $0 \leq f \leq 1$;

$k_4 = 0.6 - 0.2 f$ for $1 < f \leq 2.5$;

$k_4 = 0.1$ for $f > 2.5$;

where: $f = \frac{h_0 - H_{ice}}{D/2} - 1$

k_3 — propulsion machinery type factor, k_3 = 1 for fixed thrusters and k_3 = 1.2 for azimuthing thrusters;

Reference Number of Impacts per Propeller Rotational
Speed for Ice Classes **Table 14.2.5.1(9)**

Ice class	B1*	B1	B2	B3
Reference number of impacts (during the service life)	9×10^6	6×10^6	3.4×10^6	2.1×10^6

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

14.2.5.2 Axial design loads for open and ducted propellers

(1) Maximum ice thrust T_f and T_b on propeller for open and ducted propellers

The maximum forward and backward ice thrusts are:

$$T_f = 1.1F_f \quad \text{kN}$$

$$T_b = 1.1F_b \quad \text{kN}$$

(2) Design thrust along the propulsion shaft line for open and ducted propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward direction loads is to be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction:

$$T_r = T + 2.2\ T_f \quad \text{kN}$$

In a backward direction:

$$T_r = 1.5\ T_b \quad \text{kN}$$

If the hydrodynamic bollard thrust, T, is unknown, T is to be taken from Table 14.2.5.2(2).

Value of T *Table 14.2.5.2(2)*

Propeller type	T
CP propellers (open)	$1.25\ T_n$
CP propellers (ducted)	$1.1\ T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85\ T_n$
FP propellers driven by diesel engine (ducted)	$0.75\ T_n$

Note: T_n is the nominal propeller thrust at MCR in free running open water condition.

14.2.5.3 Torsional design loads

(1) Design ice torque Q_{max} on propeller for open propellers (maximum value during the service life of the ship)

For $D \le D_{limit}$

$$Q_{max} = 10.9\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \quad \text{kN·m}$$

For $D > D_{limit}$

$$Q_{max} = 20.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}{}^{1.1} \quad \text{kN·m}$$

where: $D_{limit} = 1.8\ H_{ice}$;

n — rotational propeller speed at MCR, in r/s, in bollard condition. If unknown, n is to be taken from Table 14.2.5.3(1):

Value of n *Table 14.2.5.3(1)*

Propeller type	n
CP propellers (open)	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine (open)	$0.85\ n_n$

Note: n_n is the nominal rotational speed at MCR in free running open water condition.

For CP propellers, the propeller pitch $P_{0.7}$ is to correspond to MCR in bollard condition, i.e. taken as $P_{0.7b}$. If unknown, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

(2) Design ice torque Q_{max} on propeller for ducted propellers (maximum value during the service life of the ship)

For $D \le D_{limit}$

$$Q_{max} = 7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kN·m}$$

For $D > D_{limit}$

$$Q_{max} = 14.6\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}{}^{1.1} \qquad \text{kN·m}$$

where: $D_{limit} = 1.8\,H_{ice}$;

n — rotational propeller speed at MCR, in r/s, in bollard condition. If unknown, n is to be taken from Table 14.2.5.3(1).

For CP propellers, the propeller pitch $P_{0.7}$ is to correspond to MCR in bollard condition, i.e. taken as $P_{0.7b}$. If unknown, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

(3) Design torque for non-resonant shaft lines

If there is no bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, the maximum response torque estimated by the equation below can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{e\max} + Q_{vib} + Q_{\max}\frac{I_e}{I_t} \qquad \text{kNm}$$

and other plants

$$Q_{peak} = Q_{e\max} + Q_{\max}\frac{I_e}{I_t} \qquad \text{kNm}$$

where all the torques and the inertia moments are to be converted to equivalent values at the rotation speed of the component being examined.

If the maximum torque Q_{emax} is unknown, it is to be taken from Table 14.2.5.3(3):

Value of Q_{emax} *Table 14.2.5.3(3)*

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Note: Q_{motor} is the electric motor peak torque.

(4) Design torque for shaft lines having resonances

If there is bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, the design torque (Q_{peak}) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. There are two alternative ways of performing the dynamic analysis.

1. Time domain calculation for estimated milling sequence excitation
2. Frequency domain calculation for blade orders sinusoidal excitation.

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

① Time domain calculation of torsional response

Time domain calculations are to be calculated for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given in this chapter, for a case where a propeller is milling an ice block, is to be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to 14.2.5.3.

Diesel engine plants without an elastic coupling are to be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses are to be included in the calculations and their standard steady state harmonics can be used.
If there is a blade order resonance just above the MCR speed, calculations are to cover rotational speeds up to 105% of the MCR speed.
The propeller ice torque excitation for shaft line transient dynamic analysis is to be defined as a sequence of blade impacts which are of a half sine shape.The torque resulting from a single blade ice impact as a function of the propeller rotation angle is as follows:
For For $\varphi = 0 \ldots \alpha_i$

$$Q(\varphi) = C_q Q_{max} \sin\left[\varphi\left(180/\alpha_i\right)\right] \quad \text{kN·m}$$

$\varphi = \alpha_i \ldots\ldots 360$

$$Q(\varphi) = 0 \quad \text{kN·m}$$

Where φ is the rotation angle from when the first impact occurs; α_i is the duration of propeller blade/ice interaction expressed in terms of the propeller rotation angle (see Figure 14.2.5.3(4)①-1); the parameters C_q and α_i are given in Table 14.2.5.3(4)①.

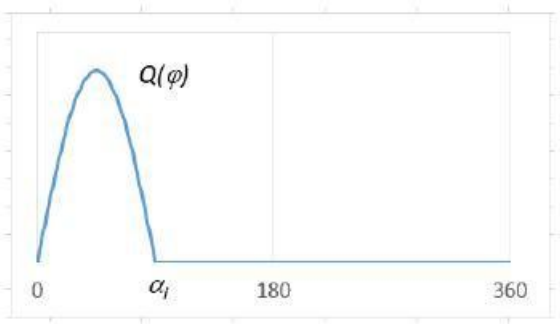


Figure 14.2.5.3(4)①-1 Schematic ice torque due to a single blade ice impact as a function of the propeller rotation angle

Values of Ice Impact Magnification Factor C_q **and Duration Factor α_i** **Table 14.2.5.3(4)①**

Torque excitation	Propeller/ice interaction	C_q	α_i(°)			
			Z=3	Z=4	Z=5	Z=6
Case 1	Single ice block	0.75	90	90	72	60
Case 2	Single ice block	1.0	135	135	135	135
Case 3	Two ice blocks (phase shift 360°/2/Z)	0.5	45	45	36	30
Case 4	Single ice block	0.5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360°/Z, see Figure 14.2.5.3(4)①-2. In addition, at the beginning and at the end of the milling sequence a linear ramp function is to be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different Z numbers in Figure 14.2.5.3(4)①-2).
The number of propeller revolutions during a milling sequence may be obtained as follows:

$$N_Q = 2H_{ice}$$

The number of impacts for blade order excitation is:

$$Z\ N_Q$$

An illustration of all excitation cases for different numbers of blades is given in Figure 14.2.5.3(4)①-2.
A dynamic simulation is to be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation is also to cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.
If a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process is to be used.

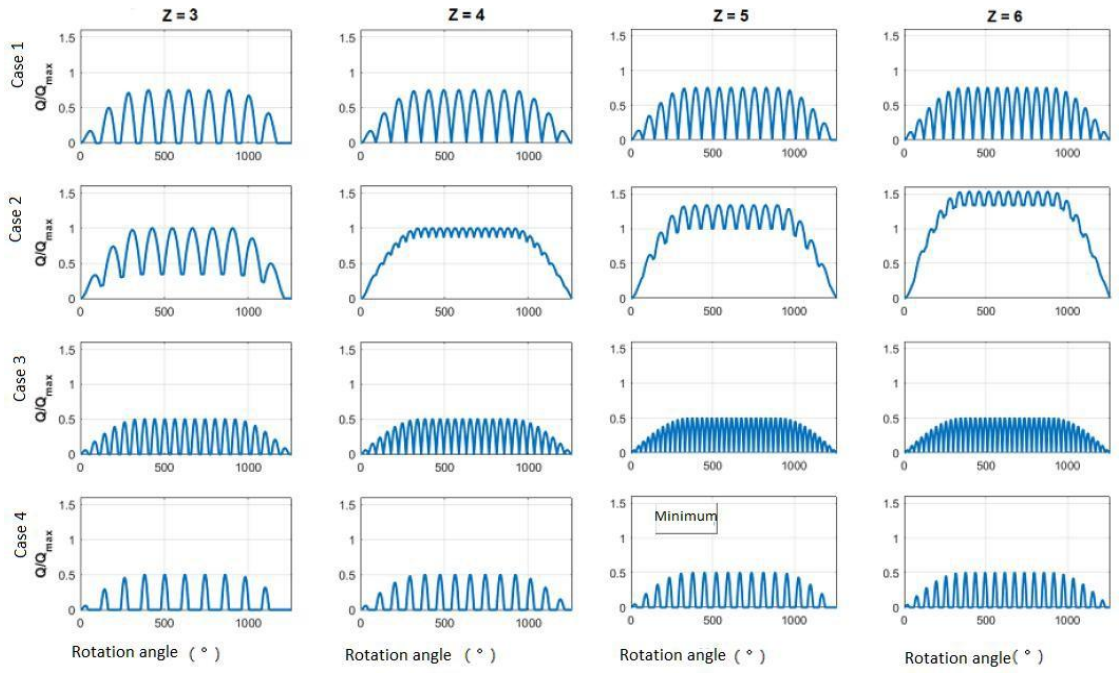


Figure 14.2.5.3(4)①-2 –The shape of the propeller ice torque excitation sequences for propellers with 3, 4, 5 or 6 blades

For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the response torques are to be obtained using the formula:

$$Q_{peak} = Q_{e\max} + Q_{rtd} \qquad \text{kNm}$$

where: Q_{rtd} is the maximum simulated torque obtained from the time domain analysis.

② Frequency domain calculation of torsional response

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. The propeller ice torque is then:

where: φ — rotation angle;

$$Q_F(\varphi) = Q_{\max} \cdot \left[C_{q0} + C_{q1} \cdot \sin\left(Z \cdot E_0 \cdot \varphi + \alpha_1\right) + C_{q2} \cdot \sin\left(2Z \cdot E_0 \cdot \varphi + \alpha_2\right) \right] \qquad \text{kNm}$$

α_1, α_2— phase angles of the excitation component;

C_{q0}—mean torque parameter;

C_{q1}—the first blade order excitation parameter;

C_{q2}—the second blade order excitation parameter;

E_0—the number of ice blocks in contact.

The values of the parameters for frequency domain excitation calculation are given in Table 14.2.5.3(4)②.

Coefficient values for frequency domain excitation calculation **Table 14.2.5.3(4)②**

Torque excitation	Z=3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.375	0.375	-90	0	0	1
Excitation case 2	0.7	0.33	-90	0.05	-45	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=4					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	0.9375	0	-90	0.0625	-90	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=5					

	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	1.19	0.17	-90	0.02	-90	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=6					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.375	-90	0.05	-90	1
Excitation case 2	1.435	0.1	-90	0	0	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1

The design torque for the frequency domain excitation case is to be obtained using the formula:

$$Q_{peak} = Q_{\max} + Q_{vib} + \left(Q_{\max}^{n} C_{q0}\right) I_e / I_t + Q_{rf1} + Q_{rf2} \qquad \text{kNm}$$

where: Q_{max}^{n} — the maximum propeller ice torque at the operation speed in consideration;

C_{q0} — mean torque parameter, see Table 14.2.5.3(4)②;

Q_{rf1} — the blade order torsional response from the frequency domain analysis;

Q_{rf2} — the second order blade torsional response from the frequency domain analysis.

If the prime mover maximum torque, Q_{emax}, is not known, it is to be taken as given in Table 14.2.5.3(3). All the torque values have to be scaled to the shaft revolutions for the component in question.

③ Guidance for torsional vibration calculation

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller. The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is extremely relevant to propulsion lines with directly driven combustion engines. Time domain calculations are to be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation. The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

14.2.5.4 Blade failure load

(1) Bending force, F_{ex}

The ultimate load resulting from blade failure as a result of plastic bending around the blade root is to be calculated with the formula below, or alternatively by means of an appropriate stress analysis, reflecting the non-linear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section. The ultimate load is assumed to be acting on the blade at the 0.8 R radius in the weakest direction of the blade. A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter D.

$$F_{ex} = \frac{0.3ct^2\sigma_{refl}}{0.8D - 2r} \times 10^3 \qquad \text{kN}$$

where: $\sigma_{refl} = 0.6\sigma_{0.2} + 0.4\sigma_u$;

c, t and r are respectively the chord length, maximum thickness, and radius of the cylindrical root section of the blade at the weakest section outside the root fillet.

(2) Spindle torque, Q_{sex}

The maximum spindle torque due to a blade failure load acting at 0.8R is to be determined.

The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque is to be defined by an appropriate stress analysis or using the equation given below.

$$Q_{sex} = \max(C_{LE\,0.8}, 0.8C_{TE\,0.8})C_{spex}F_{ex}$$

where: $C_{spex} = C_{sp}C_{fex} = 0.7\left[1-\left(4\frac{EAR}{Z}\right)^3\right]$;

C_{sp} — a non-dimensional parameter taking account of the spindle arm;

C_{fex} —a non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque;

C_{spex} —If C_{spex} is below 0.3, a value of 0.3 is to be used for C_{spex};

$C_{LE0.8}$ —the leading edge portion of the chord length at 0.8R;

$C_{TE0.8}$ —the trailing edge portion of the chord length at 0.8R.

Figure 14.2.5.4(2) illustrates the spindle torque values due to blade failure loads across the entire chord length.

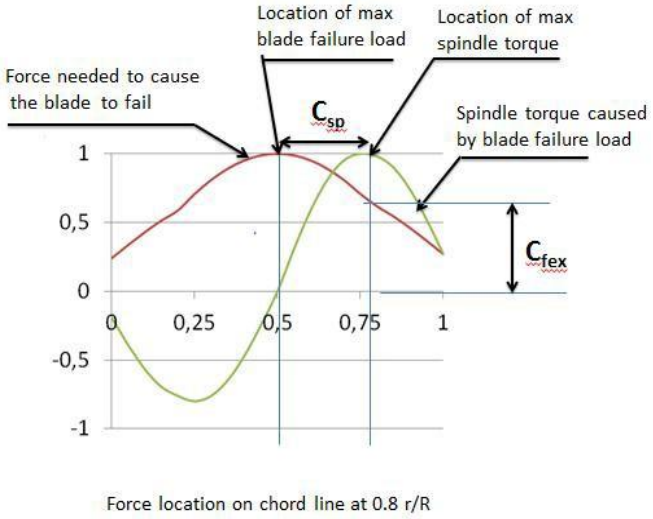


Figure 14.2.5.4(2)Schematic figure showing a blade failure load and the related spindle torque when the force acts at a different location on the chord line at radius 0.8R

14.2.6 Design

14.2.6.1 Design principle

The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components.

14.2.6.2 Propeller blade

(1) Calculation of blade stresses

The blade stresses are to be calculated for the design loads given in paragraph 14.2.5.1. Finite element analysis is to be used for stress analysis of all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area (r/R < 0.5). The root area dimensions can be accepted even if the finite element analysis would show greater stresses at the root area.

$$\sigma_{st} = A_1 \frac{M_{BL}}{100 \times ct^2} \quad \text{MPa}$$

where the constant A_1 is the ratio of the actual stress to the stress obtained with beam equation. If the actual value is not available, A_1 is to be taken as 1.6. $M_{BL} = (0.75 - r/R)RF$ for the relative radius r/R < 0.5, where F is F_b or F_f, whichever is greater.

(2) Acceptability criterion

The following criterion for calculated blade stresses is to be fulfilled:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where: σ_{st} — calculated stress for the design loads. If finite element analysis is used in estimating the stresses, equivalent von Mises stresses are to be used;

σ_{ref2} — reference stress, taken as the lesser of $0.7\sigma_u$ and $(0.6\sigma_{0.2} + 0.4\sigma_u)$.

(3) Fatigue design of propeller blade

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue should be fulfilled as given in this paragraph. The equivalent stress cycles are specified as 1×10^8.

For materials with a two-slope SN curve (see Figure 14.2.6.2(3)-1), if the following criterion is fulfilled, fatigue calculations according to this Chapter are not required:

$$\sigma_{\exp} \geq B_1 \cdot \sigma_{ref2}{}^{B_2} \cdot \log(N_{ice})^{B_3}$$

where coefficients B_1, B_2 and B_3 for open and ducted propellers are given in the Table 14.2.6.2(3).

Values of B_1, B_2 and B_3 *Table 14.2.6.2(3)*

Coefficient	Open propeller	Ducted propeller
B_1	0.00328	0.00223
B_2	1.0076	1.0071
B_3	2.101	2.471

Two types of S-N curves are available for calculation of equivalent stresses. The two-slope S-N curve (slopes 4.5 and 10) is shown in Figure 14.2.6.2(3)-1 and the one-slope S-N curve (the slope can be chosen) in Figure 14.2.6.2(3)-2.

The type of the S-N curve is to be selected to correspond to the material properties of the blade. If the S-N curve is unknown, the two-slope S-N curve is to be used.

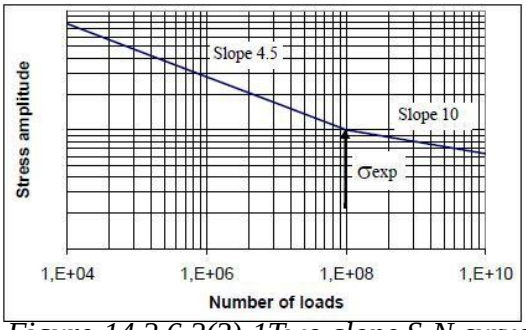


Figure 14.2.6.2(3)-1Two-slope S-N curve

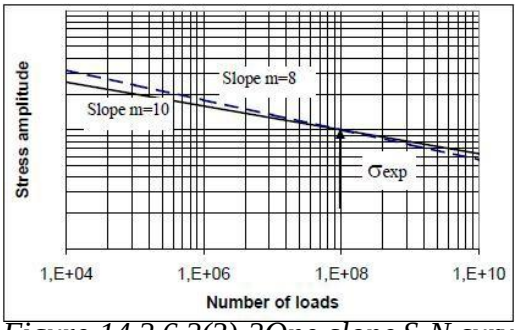


Figure 14.2.6.2(3)-2One-slope S-N curve

① Equivalent fatigue stress

The equivalent fatigue stress for 10^8 stress cycles which produces the same fatigue damage as the load distribution for the service life of the ship is:

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{\max} \quad \text{MPa}$$

where: $(\sigma_{ice})_{\max}$ — mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied, determined as follows:

$$(\sigma_{ice})_{\max} = 0.5 \cdot \left((\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max}\right) \quad \text{MPa}$$

where $(\sigma_{ice})_{f\max}$ is the principal stress resulting from forward load and $(\sigma_{ice})_{b\max}$ the principal stress resulting from backward load.

In calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{f\max}$, and $(\sigma_{ice})_{b\max}$ calculations. Case 5 is excluded from the fatigue analysis.

② Calculation of ρ parameter for two-slope S-N curve

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formulae.

$$\rho = C_1 \cdot (\sigma_{ice})_{\max}{}^{C_2} \cdot \sigma_{fl}{}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{\exp}$

where $\gamma_{\varepsilon 1}$ and $\gamma_{\varepsilon 2}$ are respectively the reduction factor for scatter and test specimen size effect, γ_v the reduction factor for variable amplitude loading, and γ_m the reduction factor for mean stress, and $\gamma_\varepsilon = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} = 0.67$, $\gamma_v = 0.75$, and $\gamma_m = 0.75$ if actual values are not available; $\sigma_{\exp}$ is the mean fatigue strength of the blade material at 10^8 cycles to failure in seawater.

The values of coefficients C_1, C_2, C_3 and C_4 are given in Table 14.2.6.2(3)②.

Values of C_1, C_2, C_3 and C_4 **Table 14.2.6.2(3)②**

Coefficient	Open propeller	Ducted propeller
C_1	0.000747	0.000534
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.22	2.584

③ Calculation of ρ parameter for one-slope S-N curve

For materials with a one-slope S-N curve, as shown in Figure 14.2.6.2(3)-2, the ρ factor is to be calculated as follows:

$$\rho = \left(G \frac{N_{ice}}{N_R} \right)^{1/m} (\ln(N_{ice}))^{-1/k}$$

where: k — shape parameter of the Weibull distribution, k = 1.0 for ducted propellers and k = 0.75 for open propellers;

N_R — reference number of load cycles, taken as10^8;

N_{ice} —range is $5\times10^6 \le N_{ice} \le 10^8$;

G — Values for the G parameter are given in Table 14.2.6.2(3)③; linear interpolation may be used to calculate the G value for other m/k ratios than given in the Table.

Values of the Parameter G for Different m/k Ratios **Table 14.2.6.2(3)③**

m/k	G	m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.623E6		

④ Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on the blade is to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \ge 1.5$$

where: σ_{fl} — characteristic fatigue strength of the blade material, in MPa, calculated as in 14.2.6.2(3)②;

σ_{fat}— equivalent fatigue ice load stress amplitude, in MPa, for 10^8 stress cycles.

14.2.6.3 Propeller bossing and CP mechanism

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft are to be designed to withstand the maximum and fatigue design loads, as defined in paragraph 14.2.5. The safety factor against yielding is to be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending, as defined in paragraph 14.2.5.4, is to be greater than 1.0 against yielding.

14.2.6.4 Propulsion shaft line

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in paragraph 14.2.5. The safety factor is to be at least 1.3 against yielding for extreme operational loads, 1.5 for fatigue loads and 1.0 against yielding for the blade failure load.

(1) Shafts and shafting components

The ultimate load resulting from total blade failure, as defined in paragraph 14.2.5.4, should not cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

14.2.6.5 Azimuthing main propulsors

(1) Design principle

In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters are to be designed for thruster body/ice interaction loads. Load formulae are given for estimating once in a lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters. Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in Figure 14.2.6.5(1). In addition, blade order thruster body vibration responses may be estimated for propeller excitation. The following load scenario types are considered:

① Ice block impact on the thruster body or propeller hub;
② Thruster penetration into an ice ridge that has a thick consolidated layer;
③ Vibratory response of the thruster at blade order frequency.

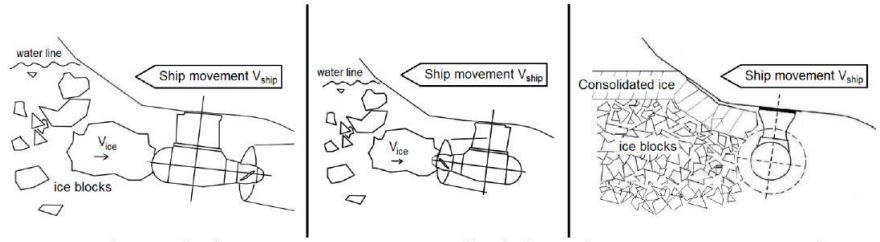


Figure 14.2.6.5(1) Examples of load scenario types

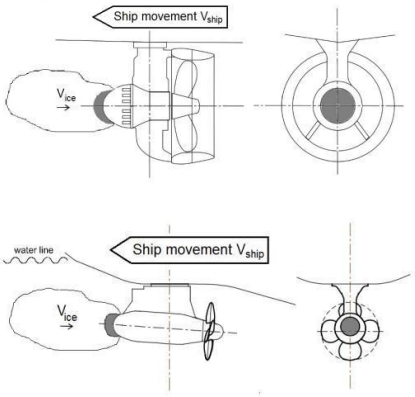
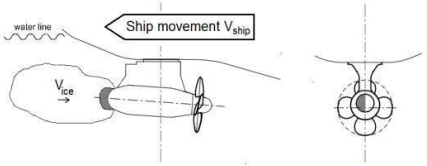
The steering mechanism, the fitting of the unit, and the body of the thruster are to be designed to withstand the plastic bending of a blade without damage. The loss of a blade is to be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

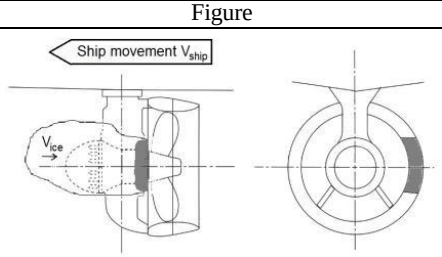
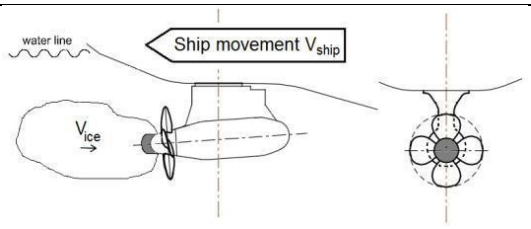
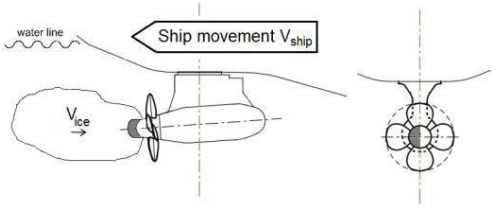
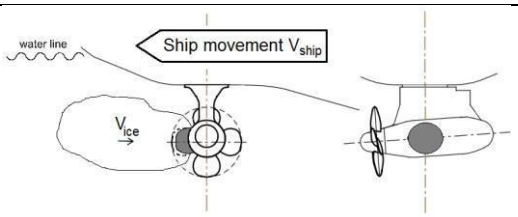
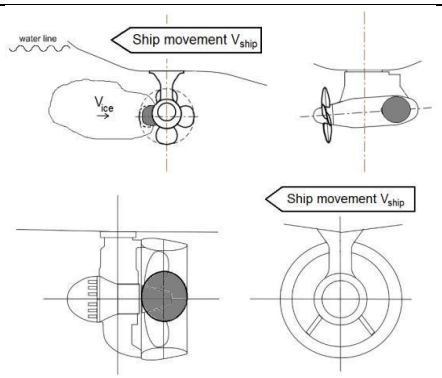
(2) Extreme ice impact loads

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub. Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster is to withstand the loads occurring when the design ice block defined in Table 14.2.3.2 impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in Table 14.2.6.5(2)-1. The contact geometry is estimated to be hemi-spherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius is to be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

Load cases for azimuthing thruster ice impact loads *Table 14.2.6.5(2)-1*

Load case	Force	Loaded area	Figure
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area	

Load case	Force	Loaded area	Figure
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz})*the contact height (H_{ice})	
Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius R to be taken from the nozzle length (L_{nz})	

The ice impact contact load is to be calculated using the formula below. The related parameter values are given in Table 14.2.6.5(2)-2. The design operation speed in ice can be derived from Tables 14.2.6.5(2)-3 and 14.2.6.5(2)-4, or the ship in question's actual design operation speed in ice can be used. The longitudinal impact speed in Tables 14.2.6.5(2)-3 and 14.2.6.5(2)-4 refers to the impact in the thruster's main operational direction. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

$$F_{ti} = 34.5 C_{DMI} R_c^{0.5} \left(m_{ice} v_s^2 \right)^{0.333} \text{kN}$$

where: R_C —impacting part sphere radius, see Figure 14.2.6.5(2), in m;
m_{ice} —ice block mass, in kg;
V_s —ship speed at the time of contact, in m/s;
C_{DM1}—dynamic magnification factor for impact loads.

C_{DM1} is to be taken from Table 14.2.6.5(2)-2 if unknown.

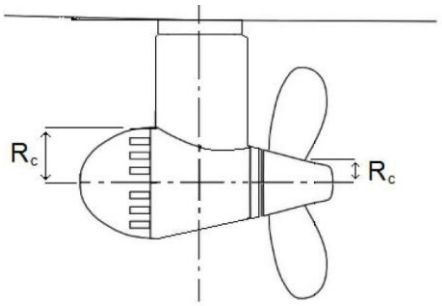


Figure 14.2.6.5(2) Dimensions used for R_c

For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius is to be estimated using the equation below.

$$R_{ceq} = \sqrt{\frac{A}{\pi}} \text{ m}$$

If the $2R_{ceq}$ is greater than the ice block thickness, the radius is set to half of the ice block thickness. For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius. For the impact on the propeller hub, the hub diameter can be used as a basis for the radius.

Parameter values for ice dimensions and dynamic magnification **Table 14.2.6.5(2)-2**

Ice class	B1*	B1	B2	B3
Thickness of the design ice block impacting thruster (2/3 of H_{ice}) (m)	1.17	1.0	0.8	0.67
Extreme ice block mass (m_{ice}) (kg)	8670	5460	2800	1600
C_{DMI} (if not known)	1.3	1.2	1.1	1

Impact speeds for aft centerline thruster **Table 14.2.6.5(2)-3**

Ice class	B1*	B1	B2	B3
Longitudinal impact in main operational direction (m/s)	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact) (m/s)	4	3	3	3
Transversal impact in bow first operation (m/s)	3	2	2	2
Transversal impact in stern first operation (double acting ship) (m/s)	4	3	3	3

Impact speeds for aft wing, bow centerline and bow wing thrusters **Table 14.2.6.5(2)-4**

Ice class	B1*	B1	B2	B3
Longitudinal impact in main operational direction (m/s)	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact) (m/s)	4	3	3	3
Transversal impact (m/s)	4	3	3	3

(3) Extreme ice loads on thruster hull when penetrating an ice ridge

In icy conditions, ships typically operate in ice channels. When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of B1* class ships in particular, because they may operate independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The load magnitude is to be estimated for the load cases shown in Table 14.2.6.5(3)-1, using the equation below. The parameter values for calculations are given in Table 14.2.6.5(3)-2 and Table 14.2.6.5(3)-3. The loads are to be applied as uniform distributed load or uniform pressure over the thruster surface. The design operation speed in ice can be derived from Table 14.2.6.5(3)-2 or Table 14.2.6.5(3)-3. Alternatively, the actual design operation speed in ice of the ship in question can be used.

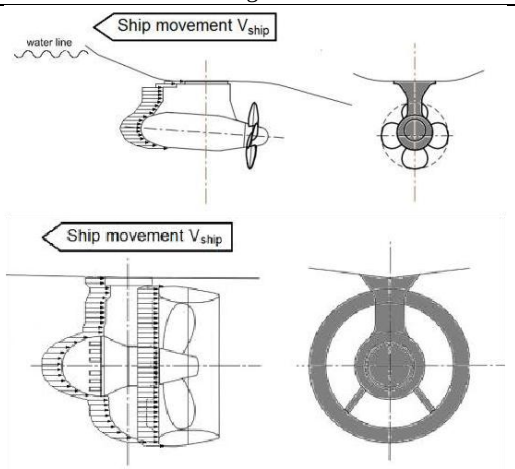
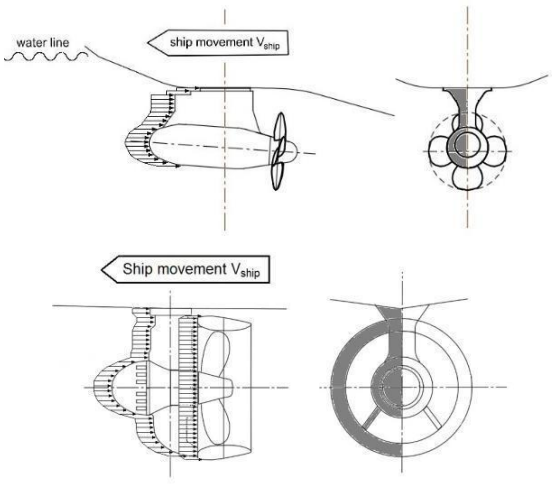
$$F_{tr} = 32 v_s^{0.66} H_r^{0.9} A_t^{0.74} \qquad \text{kN}$$

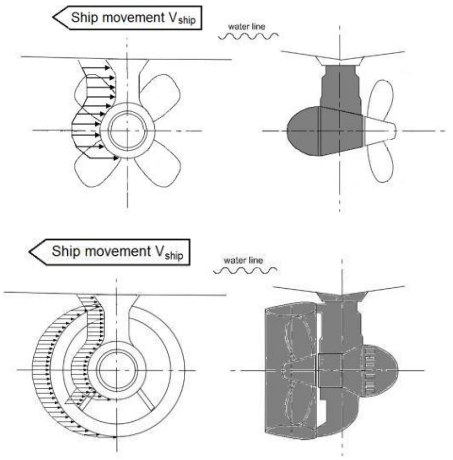
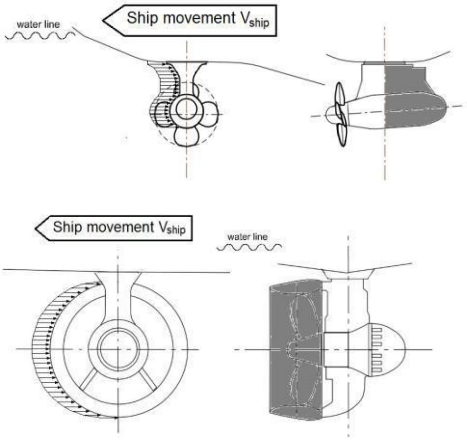
where: V_s— ship speed, in m/s;

H_r— design ridge thickness (the thickness of the consolidated layer is 18% of the total ridge thickness), in m;

A_t —projected area of the thruster, in m^2.

Load cases for ridge ice loads Table 14.2.6.5(3)-1

Load case	Force	Loaded area	Figure
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T4b Non-symmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area	

Load case	Force	Loaded area	Figure
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area	
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	*50% of* F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area	

When calculating the contact area for thruster-ridge interaction, the loaded area in the vertical direction is limited to the ice ridge thickness, as shown in Figure 14.2.6.5(3).

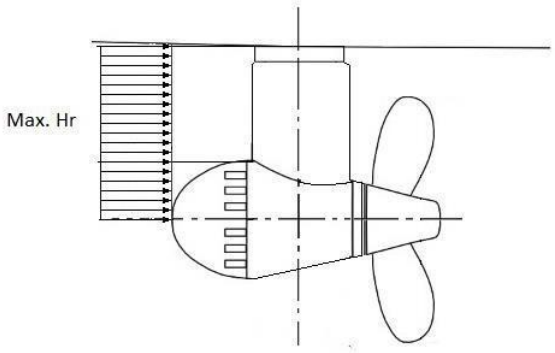


Figure 14.2.6.5(3) Schematic figure showing the reduction of the contact area by the maximum ridge thickness

Parameters for calculating maximum loads when the thruster penetrates an ice ridge (aft thrusters. bow first operation)

Table 14.2.6.5(3)-2

Ice class	B1*	B1	B2	B3
Thickness of the design ridge consolidated layer (m)	1.5	1.5	1.2	1.0
Total thickness of the design ridge, H_r (m)	8	8	6.5	5
Initial ridge	4	2	2	2

Ice class	B1*	B1	B2	B3
penetration speed (longitudinal loads) (m/s)				
Initial ridge penetration speed (transversal loads) (m/s)	2	1	1	1

Parameters for calculating maximum loads when the thruster penetrates an ice ridge (thruster first mode such as double acting ships)

Table 14.2.6.5(3)-3

Ice class	B1*	B1	B2	B3
Thickness of the design ridge consolidated layer (m)	1.5	1.5	1.2	1.0
Total thickness of the design ridge, H_r (m)	8	8	6.5	5
Initial ridge penetration speed (longitudinal loads) (m/s)	6	4	4	4
Initial ridge penetration speed (transversal loads) (m/s)	3	2	2	2

(4) Acceptability criterion for static loads

The stresses on the thruster are to be calculated for the extreme once-in-a-lifetime loads described in 14.2.6.5. The nominal von Mises stresses on the thruster body are to have a safety margin of 1.3 against the yielding strength of the material. At areas of local stress concentrations, stresses are to have a safety margin of 1.0 against yielding. The slewing bearing, bolt connections and other components are to be able to maintain operability without incurring damage that requires repair when subject to the loads given in 14.2.6.5(2) and 14.2.6.5(3) multiplied by a safety factor of 1.3.

(5) Thruster body global vibration

Evaluating the global vibratory behavior of the thruster body is important, if the first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller rotational speeds are in the high power range of the propulsion line. This evaluation is mandatory and it is to be shown that there is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power) or that the structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water are to be taken into account. In addition to this, the effect of ship attachment stiffness is to be modelled.

14.2.7 *Alternative designs*

14.2.7.1 Scope

As an alternative to paragraphs 14.2.5 and 14.2.6, a comprehensive design study may be carried out to the satisfaction of the Administration. The study is to be based on ice conditions given for different ice classes in paragraph 14.2.3, and is to include both fatigue and maximum load design calculations and fulfill the pyramid strength principle, as given in paragraph 14.2.6.1.

14.2.7.2 Loading

Loads on the propeller blade and propulsion system are to be based on an acceptable estimation of hydrodynamic and ice loads.

14.2.7.3 Design levels

The analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blades, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.

Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

Vibration analysis is to be carried out and is to indicate that the complete dynamic system is free from

harmful torsional resonances resulting from propeller/ice interaction.

Section 3 STARTING ARRANGEMENTS AND COOLING WATER SYSTEM

14.3.1 *Starting arrangements*

14.3.1.1 The capacity of the air receivers is to comply with the provisions of 9.5.1.6 of this PART. If the air receivers serve any other services than starting the propulsion engine, their capacity is to be adequately increased.

14.3.1.2 The capacity of the air compressors is to comply with the provisions of 9.5.1.2 of this PART. If the ship is intended for Ice Class B1* and its propulsion engine is of reversible type, the charging time specified in 9.5.1.2 of this PART is not to be more than 0.5 h.

14.3.2 *Cooling water system*

14.3.2.1 The cooling water system is to be designed to ensure supply of cooling water when navigating in ice. For this purpose at least one cooling water inlet chest is to be arranged as follows:

(1) The sea inlet is to be situated near the centerline of the ship and well aft if possible.

(2) The chest is to have a sufficient volume. As a guidance for design, the volume of the chest is to be about one cubic metre for every 750 kW of engine output of the ship including the output of the auxiliary engines necessary for the ship's service.

(3) The chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.

(4) A pipe, being of the same diameter as the cooling water discharge pipe, is to be connected between the chest and the cooling water discharge pipe.

(5) The area of the strum holes is not to be less than 4 times the inlet pipe sectional area.

14.3.2.2 If there are difficulties to meet the requirements of 14.3.2.1(2) and (3), two smaller chests may be arranged, but they must comply with the requirements of 14.3.2.1(1) to (5).

14.3.2.3 Heating coils may be installed in the upper part of the chest or chests where necessary.

14.3.2.4 Arrangements for using ballast water for cooling purposes may be used as a reserve in ballast condition but can not be accepted as a substitute for sea inlet chests as described above.

CHAPTER 15 VAPOUR CONTROL SYSTEM

Section 1 GENERAL PROVISIONS

15.1.1 *Application*

15.1.1.1 The requirements of this Chapter are applicable to ships fitted with systems for control of vapour emission from tanks and requesting sub-elements① as defined in 15.1.2, such as oil tankers and chemical tankers, etc.

15.1.1.2 In addition to the requirements of this Chapter, attention is to be given to any relevant regulations (if any) of the Administration of the flag States in which the ship is to be registered.

15.1.2 *Sub-elements*

15.1.2.1 Ships fitted with systems for control of vapour emission from cargo tanks complying with all requirements of this Chapter (other than Section 4) may be assigned to the following sub-elements:

VCS

15.1.2.2 Ships fitted with systems for control of vapour emission from cargo tanks complying with all requirements of this Chapter may be assigned to the following sub-elements:

VCS-T

15.1.3 *Definitions*

15.1.3.1 For the purpose of this Chapter:

(1) **Diluted** means a flammable gas or mixture is defined as diluted when its concentration in air is less than 50% of its lower explosive limit.

(2) **Flammable cargoes** are crude oils, petroleum products and chemicals having a flashpoint not exceeding 60℃ (closed cup test) and a Reid vapour pressure which is below the atmosphere pressure, and other substances having equivalent fire risk.

(3) **Inerted** is the condition in which the oxygen content in a flammable gas/air mixture is 8% or less by volume.

(4) **Independent** is suitable for two electrical systems which are considered independent when any one system may continue to operate with a failure of any part of the other system, except the power source and electrical feeder panels.

(5) **Maximum transfer rate** is the maximum volumetric rate at which a ship may receive cargo or ballast.

(6) **Service ship** is a ship which receives and transports liquid cargoes between a facility (shore station) and another ship and vice versa.

(7) **Lightering operation** is the operation of transferring liquid cargo from one ship to one service ship.

(8) **Topping-off** is the operation of transfer of liquid cargo from a service ship to another ship in order to load the receiving ship at a deeper draft.

(9) **Ship vapour connection** is the point of interface between the ship's fixed vapour collection system and the collection system of a facility or another ship. Hoses or loading arms on board, carried for the purpose of these Rules, are considered part of the vapour control system of the ship.

(10) **Terminal vapour connection** is that point at which the terminal vapour collection system is connected to a vapour collection hose or arm.

(11) **Vapour balancing** is the transfer of vapour displaced by incoming cargo from the tank of a ship receiving cargo into a tank of a facility delivering cargo via a vapour collection system.

(12) **Vapour collection system** is an arrangement of piping and hoses used to collect vapour emitted from a ship's cargo tank and to transport the vapour to a vapour processing unit.

(13) **Vapour processing unit** is that component of a vapour control system that recovers or destroys vapour collected from a ship.

15.1.4 *Plans and documents*

15.1.4.1 The following plans and documents are to be submitted for approval by ships for which the sub-elements of VCS or VCS-T is requested:

(1) Diagrammatic plan of the vapour piping system, indicating material specifications, scantlings, ratings, joining details and fittings;

(2) Diagrammatic plan of the gauging system and overfill protection, indicating manufacturer and type of

① Sub-elements: refer to Table 1.3.3.1 of Chapter 1 of Rules for Green Eco-ships.

the equipment or instruments, hazardous area locations, location of electrical equipment in gas–dangerous spaces and safe certificates of the electrical instruments intended to be used in hazardous locations, electrical schemes concerning the alarm system supply, electrical schemes concerning the intrinsically safe circuits;

(3) Diagrammatic plan of the venting system, indicating necessary data for verifying the venting capacity of the pressure/vacuum valves;

(4) Pressure drop calculation comparing cargo transfer rates versus pressure drops from the farthest tanks to the vapour connection, including any possible hoses;

(5) Calculations showing the time available between alarm setting and overfill at maximum loading rate for each tank;

(6) Instruction manual.

15.1.4.2 The following additional plans and documents are also to be submitted for reference by ships for which the sub-elements of VCS-T is requested:

Information on the anti-detonation devices, including manufacturer and type of the device employed as well as documentation on any acceptance tests carried out.

Section 2 VAPOUR PIPING SYSTEMS

15.2.1 *General requirements*

15.2.1.1 Each ship is to have vapour collection piping permanently installed, with the tanker vapour connection located as close as practical to the loading manifolds.

Chemical tankers are permitted to have a permanent vapour connection at each cargo tank for connection to a vapour hose which is to be kept as short as practicable, and in no case longer than 3 m.

15.2.1.2 If a tanker simultaneously collects vapour from incompatible cargoes, it is to keep these incompatible vapours separate throughout the entire vapour collection system.

15.2.1.3 Vapour collection piping is to be electrically bonded to the hull and is to be electrically continuous.

15.2.1.4 Means are to be provided to eliminate liquid condensate which may collect in the system. In general, a draining valve is to be fitted in each low point of the line and the condensate is led to an appropriate collection, such as catcher groove, slop tank.

15.2.1.5 When inert gas distribution piping is used for vapour collection piping, means to isolate the inert gas supply from the vapour collection system are to be provided. The isolation device is to comply with the requirements of Chapter 4, PART SIX of the Rules.

15.2.1.6 The vapour collection system is not to interfere with the proper operation of the cargo tank venting system. However, vapour collection piping may be partly common with the vent piping or the inert gas system piping.

15.2.1.7 External connection flange of the vapour collection system is to be fitted with a permanently protruding stud in way of 12 o'clock position on the pitch circle of bolt hole with 12.7 mm in diameter and at least 25.4 mm in length.

15.2.2 *Vapour manifold*

15.2.2.1 An isolation valve capable of manual operation is to be provided at the ship vapour connection, the valve position is to be readily determined visually (open/closed indication).

15.2.2.2 Each vapour manifold is to be for the last 1m in front of external connection flange painted on its exterior surfaces with red/yellow/red. The red bands are 100 mm wide, the yellow in the center is 800 mm wide and labeled "VAPOUR" in black letters at least 50 mm high.

15.2.3 *Vapour hoses*

15.2.3.1 Each hose used for transferring vapour is to have:

(1) a maximum working pressure of at least 0.035 MPa;

(2) the capacity of withstanding at least 0.014 MPa vacuum without collapsing or constricting;

(3) a design burst pressure of at least 0.175 MPa;

(4) electrical continuity with a maximum resistance of 10 kΩ;

(5) resistance to abrasion and kinking;

(6) the last 1 m of each end of the hose marked in accordance with 15.2.2.2.

15.2.3.2 Vapour hose handling equipment is to be provided with hose saddles which provide adequate support to prevent kinking or collapse of hoses.

15.2.4 *High and low vapour pressure protection*

15.2.4.1 The cargo tank venting system is to be capable of discharging cargo vapour at 1.25 times the maximum transfer rate in such a way that the pressure in the vapour space of each tank connected to the vapour collection system does not exceed the maximum working pressure of the tank or the operating pressure/burst pressure of a safety valve or rupture disk, if fitted.

15.2.4.2 It is not to relieve at a pressure corresponding to a pressure in the cargo tank vapour space of less than 0.007 MPa.

15.2.4.3 Means are to be provided to prevent a vacuum in the cargo tank vapour space that exceeds the maximum design vacuum for any tank which is connected to the vapour collection system, when the tank is discharged at the maximum rate.

15.2.4.4 It is not to relieve at a vacuum corresponding to a vacuum in the cargo tank vapour space less than 0.0035 MPa below the atmospheric pressure.

15.2.4.5 Pressure/vacuum safety valves are to be fitted with means to check that the device operates freely and does not remain in the open position.

15.2.4.6 Pressure/vacuum safety valves are to be fitted with a flame screen at their outlets, unless the vapour discharge velocity is not less than 30 m/s.

15.2.4.7 A venting testing is to be carried out for the pressure/vacuum safety valves before being fitted. Where it is intended to comply with the requirements of 15.2.4.6, a flame screen is to be fitted when in testing.

Section 3 INSTRUMENTATION

15.3.1 *Cargo tank gauging equipment*

15.3.1.1 Each cargo tank that is connected to a vapour collection system is to be equipped with a cargo gauging device which:

(1) provides a closed gauging arrangement which does not require opening the tank to the atmosphere during cargo transfer;

(2) allows the operator to determine the liquid level in the tank for the full range of liquid levels in the tank;

(3) indicates the liquid level in the tank, at the position where cargo transfer is located;

(4) if possible, is installed in tank during the entire transfer operation.

15.3.2 *Cargo tank high level alarms*

15.3.2.1 Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe high level alarm system which alarms before the tank overfill alarm, but not lower than 95% of the tank capacity.

15.3.2.2 The high level alarm is to be capable of giving audible and visual alarm indications at the cargo transfer control room. It is to be identified with the black letters “HIGH LEVEL ALARM” with at least 50 mm high.

15.3.2.3 The high level alarm is to be independent of the overfill alarm.

15.3.2.4 The high level alarm is to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors.

15.3.2.5 The high level alarm is to be able to be checked at the tank of proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

15.3.3 *Cargo tank overfill alarms*

15.3.3.1 Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe overfill alarm which alarms early enough to allow the person in charge of transfer operation to stop such operation before the cargo tank overflows.

In general, the setting of cargo tank overfill alarm is not to exceed 98.5% of the tank capacity, and the time between alarm setting and overfill is not to be less than 1 min.

15.3.3.2 The overfill alarm is to be given audible and visual alarm indications at the cargo transfer control room and in the deck cargo area, and the audible and visual alarm indications can also be seen and heard at most positions. It is to be identified with the black letters “OVERFILL ALARM” with at least 50 mm high.

15.3.3.3 The overfill alarm is to be independent of both the high level alarm and the cargo gauging system.

15.3.3.4 The overfill alarm is to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors.

15.3.3.5 The overfill alarm is to be able to be checked at the tank of proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

15.3.4 *High and low vapour pressure alarms*

15.3.4.1 Each vapour collection system is to be fitted with one or more pressure sensing devices that sense the pressure in the main collection line, and which:

(1) have a pressure indicator and audile and visual alarm indications located in the cargo transfer control room;

(2) alarm the high pressure at not more than 90% of the lowest relief valve setting in the tank venting system;

(3) alarm at a low pressure of not less than 0.001 MPa (100 mm WG) for an inerted tank, or the lowest vacuum relief valve setting in the cargo venting system for a non-inerted tank.

15.3.4.2 Pressure sensors fitted in each cargo tank are acceptable as equivalent to pressure sensors fitted in each main vapour collection line.

Section 4 ADDITIONAL REQUIREMENTS FOR VCS-T

15.4.1 *Application*

15.4.1.1 The requirements of this Section are applicable to service ships.

15.4.2 *General requirements*

15.4.2.1 If the cargo tanks on a ship discharging cargo and a ship receiving cargo are inerted, the service ship is to have a means to inert the vapour transfer hose prior to transferring cargo vapour and an oxygen analyzer with a sensor or sampling connection fitted within 3 m of the ship vapour connection which:

(1) activates an audible and visual alarm at the cargo transfer control room on the service ship where the oxygen content in the vapour collection system exceeds 8% by volume;

(2) has an oxygen concentration indicator at the cargo transfer control room on the service ship;

(3) has a connection for injecting a span gas of known concentration for calibration and testing of the oxygen analyzer.

15.4.2.2 If the cargo tanks on a ship discharging cargo are not inerted, the vapour collection line on the service ship is to be fitted with an approved detonation arrester located within 3 m of the ship vapour connection.

15.4.2.3 An electrical insulating flange or one length of non-conductive hose is to be provided between the ship vapour connection on the service ship and the vapour connection on the ship being lightered or topped off.

Section 5 INSTRUCTION MANUAL

15.5.1 *General requirements*

15.5.1.1 Each ship utilizing a vapour emission control system is to be provided with a detailed instruction manual.

15.5.1.2 Instructions are to encompass the purpose and principles of operation of the vapour emission control system and provide an understanding of the equipment involved and associated hazards. In addition, the instructions are to provide an understanding of the operating procedures, piping connection sequence, start-up procedures, normal operations and emergency procedures.

15.5.2 *Content*

15.5.2.1 The instructions are to contain:

(1) a line diagram of the tanker's vapour collection piping including the location of all valves, control devices, pressure-vacuum safety valves, pressure indicators, flame arresters and detonation arresters, if fitted;

(2) the maximum transfer rate for each group of cargo tanks having the same venting line, determined as the lowest of the following:

① 80% of the total venting capacity of the pressure relief valves in the cargo tank venting system;

② the total vacuum relieving capacity of the vacuum relief valves in the cargo tank venting system;

③ the rate based on pressure drop calculations at which, for a given pressure at the facility (shore station) vapour connection, or, if lightering, at the vapour connection of the service ship, the pressure in any cargo tank connected to the vapour collection system exceeds 80% of the setting of any pressure relief valve in the cargo tank venting system;

(3) the initial loading rate for each cargo tank, to be determined in such a way as to minimize the development of a static electrical charge, where applicable;

(4) tables or graphs of transfer rates (and corresponding vapour collection system pressure drops through the vapour hoses, if foreseen) determined from the most remote cargo tanks to the ship vapour connection as follows:

① for each cargo handled by the vapour collection system at the maximum and the lowest transfer rates;

② based on 50% cargo vapour and air mixture, and a vapour growth rate appropriate for the cargo being loaded.

CHAPTER 16 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS OF SMALL SHIPS

Section 1 GENERAL PROVISIONS

16.1.1 *Application*

16.1.1.1 The provisions of this Chapter apply to the machinery installations of small ships and such provisions may substitute those fore-mentioned relevant provisions of this PART.

Section 2 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS

16.2.1 *Dead ship starting*

16.2.1.1 Cargo ships of less than 500 gross tonnage may not be required by 1.2.6 of this PART.

16.2.2 *Boiler arrangement*

16.2.2.1 For cargo ships of less than 500 gross tonnage, if effective heat-insulating measures are taken, the clearance between the boilers and the fuel oil tank boundaries as required in 1.3.2.2 of this PART may be suitably reduced.

16.2.3 *Bilge suction arrangement in machinery spaces*

16.2.3.1 For ships of less than 500 gross tonnage, the number of direct bilge suctions in Table 3.3.2.1 of this PART may be changed to 1. The number of branch suction may be changed to 2.

For ships of less than 100 gross tonnage, the number of branch suction in Table 3.3.2.1 of this PART may be changed to 1.

16.2.3.2 For cargo ships of less than 500 gross tonnage or passenger ships of less than 100 gross tonnage engaged on non-international voyage or passenger ships of less than 500 gross tonnage and with service category 3 engaged on non-international voyage, emergency bilge suction as required in 3.3.3.1 of this PART may be dispensed with.

16.2.4 *Bilge pumps and bilge piping*

16.2.4.1 The number of power bilge pumps and drive modes for each ship as specified in Table 3.4.1.1 of this PART may be required for the following ships:

(1) for passenger ships engaged on non-international voyages of less than 100 gross tonnage, carrying not more than 100 passengers, 2 independent bilge pumps may be provided if navigation period is less than 4 h;

(2) for cargo ships of less than 100 gross tonnage, one of power driven type and one hand pump may be provided.

16.2.4.2 For ships of 25 m or less in length, the internal diameter of branch bilge pipes as required in 3.4.3.4 of this PART may be reduced to 40 mm.

16.2.4.3 For ships of 60 m or less in length, the internal diameter of branch bilge pipes to the tunnel wells as required in 3.4.3.6 of this PART may be reduced to 50 mm.

16.2.4.4 For ships of less than 500 gross tonnage, the capacity of bilge wells for machinery and boiler spaces and cargo holds as specified in 3.4.8.1 of this PART may be suitably reduced but not to be less than 0.10 m^3.

16.2.4.5 For ships of less than 100 gross tonnage, the ends of bilge suction in machinery spaces as specified in 3.4.8.2 of this PART may be fitted with a strum box instead of a mud box.

16.2.5 *Fuel oil daily tank*

16.2.5.1 The requirements of 4.2.1.8 of this PART do not apply to cargo ships of less than 500 gross tonnage.

16.2.6 *Oil burning units of boilers*

16.2.6.1 For cargo ships of less than 500 gross tonnage, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil as specified in 4.2.2.2 of this PART, one oil supply unit will be accepted.

16.2.7 *Oil fuel booster pumps*

16.2.7.1 For ships of less than 500 gross tonnage, the standby pump or spare pump as required in 4.2.3.1 of this PART may be dispensed with.

16.2.8 *Feed water pumps for boilers*

16.2.8.1 For cargo ships of less than 500 gross tonnage, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil and cargo oil as specified in 4.4.1.1 of this PART, only one feed water pump fitted is acceptable.

16.2.9 *Feed water systems for boilers*

16.2.9.1 For auxiliary boilers fitted with only one feed water pump as required in 16.2.8 of this Chapter, the requirements for provision of two independent feed water systems in 4.4.2.1 of this PART are not applicable.

16.2.10 *Condensate pumps*

16.2.10.1 For cargo ships of less than 500 gross tonnage, if not propelled by steam, for condensate pumps mentioned in 4.4.4.1 of this PART, the standby pump or spare pump is dispensed with.

16.2.11 *Cooling water pumps*

16.2.11.1 For cargo ships of less than 500 gross tonnage, the standby pump or spare pump as required in 4.5.1.1 of this PART is dispensed with.

16.2.12 *Bilge lines of oil tankers*

16.2.12.1 For oil tankers of less than 150 gross tonnage, the cargo pump room bilge specified in 5.3.2.1 of this PART may be drained by means of a hand pump having a 50 mm bore suction.

16.2.13 *Oil tank air pipes*

16.2.13.1 Paragraph 3.10.2.5 of this PART does not apply to cargo ships of less than 500 gross tonnage.

16.2.14 *Oil tank short sounding pipes*

16.2.14.1 For fuel oil tanks in double bottom tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) are to be met for cargo ships of less than 500 gross tonnage.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF

SEA-GOING STEEL SHIPS

2024

PART FOUR ELECTRICAL INSTALLATIONS

Table of Contents

CHAPTER 1 GENERAL 1
Section 1 GENERAL PROVISIONS 1
Section 2 OPERATING CONDITIONS 6
Section 3 DESIGN, CONSTRUCTION AND INSTALLATION 7
CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS 15
Section 1 MAIN SOURCE OF ELECTRICAL POWER 15
Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER 17
Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER 21
Section 4 POWER SUPPLY AND DISTRIBUTION 22
Section 5 PROTECTION 25
Section 6 AUXILIARY MACHINERIES 29
Section 7 LIGHTING AND NAVIGATION LIGHTS 32
Section 8 INTERNAL COMMUNICATION SYSTEMS 33
Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD 35
Section 10 HEATING AND COOKING EQUIPMENT 39
Section 11 STORAGE BATTERIES 40
Section 12 CABLES 42
Section 13 LIGHTNING PROTECTION 53
Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS 54
Section 15 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY 58
Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS 58
Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION 61
Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS 62
Section 19 DETECTION OF WATER INGRESS IN CARGO HOLDS 66
CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT 69
Section 1 GENERAL PROVISIONS 69
Section 2 ROTATING MACHINES 69
Section 3 SWITCHGEAR ASSEMBLIES 74
Section 4 CONTROL GEAR 77
Section 5 CABLES 78
Section 6 POWER AND LIGHTING TRANSFORMERS 79
Section 7 STORAGE BATTERIES 81
Section 9 UNINTERRUPTIBLE POWER SYSTEM 83
Section 10 OTHER ELECTRICAL EQUIPMENT 84
CHAPTER 4 SUPPLEMENTARY REQUIREMENTS FOR CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE 86
Section 1 CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE 86
APPENDIX 1 SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS 87
APPENDIX 2 TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS 115

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 Unless otherwise specified, the requirements of this PART apply to electrical installations intended for sea-going ships.

1.1.1.2 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be constructed and installed in accordance with the relevant requirements of this PART, inspected and tested by the Surveyors. In addition, construction and testing of the electrical equipment are to comply with the relevant acceptable standards.

1.1.1.3 The design and installation of the electrical equipment other than those specified in 1.1.1.2 of this Section is to be such that risk of fire due to its failure is minimized, and it is at least to comply with the acceptable standards to be revised where necessary for ambient conditions.

1.1.1.4 In addition, the electrical installations are to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.5 The electrical installations are to be such that:

(1) all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;

(2) electrical services essential for safety will be ensured under various emergency conditions;

(3) the safety of passengers, crew and ship from electrical hazards will be ensured.

1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) Essential services are the equipment necessary for the propulsion, steering and safety of the ship and the special equipment on ships with special class notations, including:

① primary essential services which need to be in continuous operation for maintaining propulsion and steering:

(a) steering gear;

(b) controllable pitch propeller installation;

(c) scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines required for propulsion;

(d) forced draught fans, feed water pumps, water circulating pumps, vacuum pumps, condensate pumps and oil burning installations for auxiliary steam boilers for the operation of primary essential services and for steam plants on steam turbine ships;

(e) azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps;

(f) electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps;

(g) electric generators and associated power sources supplying the equipment mentioned in (a) to (f) above;

(h) hydraulic pumps supplying the equipment mentioned in (a) to (f) above;

(i) viscosity control equipment for heavy fuel oil;

(j) fire pumps and other extinguishing medium pumps;

(k) navigation lights, aids and signals;

(l) internal safety communication equipment;

(m) lighting system;

(n) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;

② secondary essential services which need not necessarily be in continuous operation for maintaining propulsion and steering, but which are necessary for maintaining the ship's safety, e.g.:

(a) windlasses;

(b) fuel oil transfer pumps and fuel oil treatment equipment;

(c) lubricating oil transfer pumps and lubricating oil treatment equipment;

(d) pre-heaters for heavy fuel oil;

(e) starting air and control air compressors;

(f) bilge, ballast and heeling pumps;

(g) ventilating fans for engine and boiler rooms;

(h) equipment necessary for maintaining dangerous spaces in a safe condition;
(i) fire detection and alarm system;
(j) watertight closing appliances;
(k) refrigerating equipment for lowering ambient air temperature (see 1.2.1.2 of this Chapter);
(l) electric generators and associated power sources supplying the equipment mentioned in (a) to (k) above;
(m) hydraulic pumps supplying the equipment mentioned in (a) to (k) above;
(n) control, monitoring and safety systems for cargo containment systems;
(o) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;

③ special equipment of ships with a special class notation that may be regarded as essential services.

(2) Non-essential services are those whose temporary disconnection will not impair propulsion and steer of the ship, nor endanger the safety of passengers, crew, cargo, ship and machinery.

(3) Emergency consumer is a consumer which, after loss of the main source of electrical power, must be supplied by the emergency source of electrical power.

(4) Main source of electrical power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

(5) Emergency source of electrical power is a source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.

(6) Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.

(7) Primary distribution system is a system having electrical connection with the generator.

(8) Secondary distribution system is a system having no electrical connection with the generator, e.g. isolated therefrom by a double-wound transformer.

(9) Low-voltage system is an alternating-current system operating with the maximum rated voltage not exceeding 1,000 V inclusive between conductors and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions does not exceed 1,500 V between conductors.

(10) High-voltage system is an alternating-current system operating with the rated voltage more than 1 kV but not exceeding 15 kV and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions exceed 1,500 V between conductors.

(11) Switch gear and control gear assembly is a combination of one or more switch gears and means of control, measurement, signal, protection and adjustment etc, assembled by the manufacturer together with all internal electrical and mechanical connectors and components.

(12) Main switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's services.

(13) Emergency switchboard is a switchboard which, normally supplied by the main switchboard, in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's emergency services.

(14) Distribution board is a switch gear and control gear assembly arranged for the control and distribution of electrical power to final sub-circuits.

(15) Final sub-circuit is that portion of a wiring system extending beyond the final over-current device of a board.

(16) Total discrimination (total selectivity) is an over-current discrimination where, in the presence of two or more over-current protection devices in series, the protective device on the load side effects the protection without causing the other protective devices to operate.

(17) Partial discrimination (partial selectivity) is an over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device on the load side effects the protection up to a given level of short-circuit current, without causing the other protective devices to operate.

(18) Back-up protection is the protection equipment or system which is intended to operate when a system fault is not cleared in due time because of failure or inability of the protective device closest to the fault to operate or because of failure of the other protective device.

(19) Continuity of power supply means that during and after a fault in a circuit, the supply to fault-free circuits is permanently ensured.

(20) Dangerous zone is a zone where flammable or explosive vapours, gases, dusts, or explosives may be

normally expected to accumulate.
(21) Enclosed space is a space enclosed by bulkheads and decks, which may be fitted with doors, windows or other openings capable of being closed.
(22) Semi-enclosed space is a space limited by top plates, wind breaks and bulkheads etc. in such a manner that the natural conditions of ventilation in the space are notably different from those obtained on open deck, and so arranged that the gas will not easily diffuse.
(23) A blackout situation means that the main and auxiliary machinery installations, including the main power supply, are out of operation, but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.
(24) Shelf life of a battery means the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.
(25) An air-lock is to have two gastight steel doors which are self-closing without any hold-back arrangement, and the distance between which is not to be less than 1.5 m and not necessarily more than 2.5 m.
(26) Ripple voltage
The amplitude of the ripple voltage is represented in Figure 1.1.2.1(26) by the difference between U_{max} and $U_{min.}$

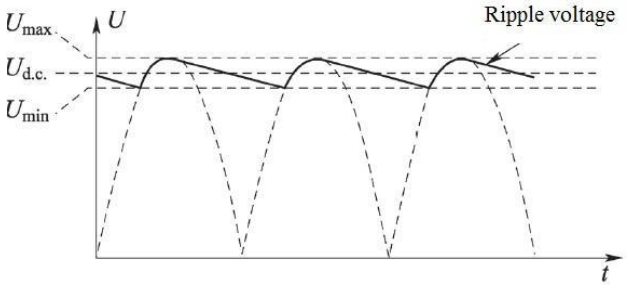


Figure 1.1.2.1(26) Ripple Voltage

(27) Uninterruptible power system (UPS) is a combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power in case of input power failure.
(28) Off-line UPS unit is a UPS unit where under normal operation the output load is powered from the bypass line (raw mains) and only transferred to the inverter if the bypass supply fails or goes outside preset limits. This transition will invariably result in a brief (typically 2 to 10 ms) break in the load supply. See Figure 1.1.2.1(28).

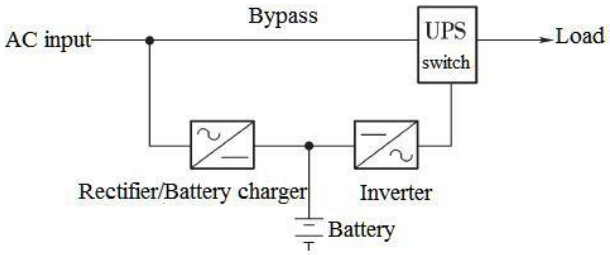


Figure 1.1.2.1(28) Off-Line UPS Unit

(29) Line interactive UPS unit is an off-line UPS unit where under normal operation the output load is powered from the UPS inverter or the power interface and when the input power goes outside the preset voltage and frequency limits, the load is transferred to stored energy power and the input power is disconnected from the power interface. See Figure 1.1.2.1(29).

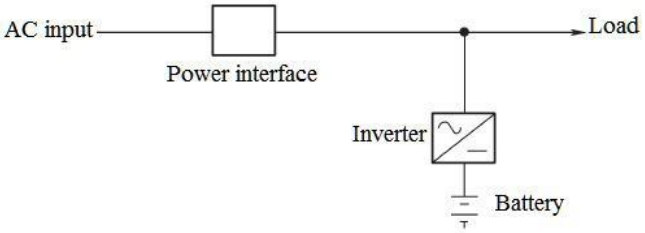


Figure 1.1.2.1(29) Line Interactive UPS Unit

(30) On-line UPS unit is a UPS unit where under normal operation the output load is powered from the inverter, and will therefore continue to operate without break in the event of the supply input failing or going outside preset limits. See Figure 1.1.2.1(30).

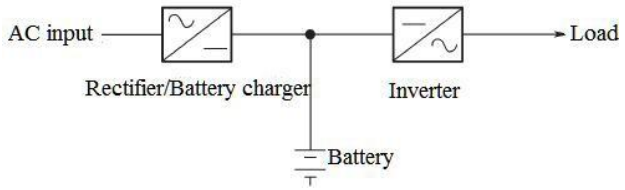


Figure 1.1.2.1(30) On-Line UPS Unit

(31) Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods.
(32) Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation.
(33) Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.1.3 Plans and documents

1.1.3.1 The following plans and documents are to be submitted for approval:
(1) Electrical loading evaluation of main and emergency sources of electrical power.
(2) Calculations for short-circuit currents (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load)of more than 250 kVA).
(3) Analysis for coordination of protective devices in compliance with the requirements of 2.5.1.1 and 2.5.4.1 of this PART (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load) of more than 250 kVA,which may be omitted for non-self-propelled ships).
(4) Diagrams of power systems, in which the following are to be indicated:
① main ratings of motors, transformers, batteries, electrical and electronic equipment;
② all feeders connected to main and emergency switchboards;
③ section boards (if fitted) and distribution boards;
④ type, cross-sectional area and current loadings of cables;
⑤ rating and setting of protective devices (such as short-circuit, overloading, reverse power and unloading protection);
⑥ remote stops;
⑦ insulation level monitoring and alarm;
⑧ interlocks..
(5) Arrangement of main electrical equipment, in which the positions of the following items are to be indicated:
① main and emergency generators;
② main and emergency switchboards (or emergency accumulator battery charging and discharging boards);
③ emergency accumulator batteries;
④ electrical equipment for essential services (see 1.1.2.1 of this Chapter).
(6) Schematic diagrams of main lighting.
(7) Arrangement of main lighting.
(8) Schematic diagrams of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).
(9) Arrangement of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).
(10) Schematic diagrams (if supplied by emergency power) of low location lighting (if fitted).
(11) Schematic diagrams of internal communication systems, including:
① engine-room telegraph system;
② essential telephone system;
③ communication system for lifesaving;
④ engineers' alarm system.
(12) Arrangement of internal communication systems, including:

① engine-room telegraph system;
② essential telephone system;
③ communication system for lifesaving;
④ engineers' alarm system.

(13) Schematic diagrams of safety systems for the ship and persons on board, including:
① general emergency alarm system;
② public address system;
③ fire detection and fire alarm systems;
④ alarm system for closing watertight doors;
⑤ other alarm systems, e.g. for the release of fire extinguishing media (see Section 9, Chapter 2 of this PART).

(14) Arrangement of safety systems for the ship and persons on board, including:
① general emergency alarm system;
② public address system;
③ fire detection and alarm system;
④ alarm system for closing watertight doors;
⑤ other alarm systems, e.g. for the release of extinguishing media (see Section 9, Chapter 2 of this PART).

(15) Arrangement of main cable runs (for passenger ships and high voltage electrical installations).

(16) General arrangement of the ship showing dangerous zones and spaces (for oil tankers and other ships carrying dangerous explosive goods).

(17) Simplified circuit diagram of electrical propulsion system, in which the following are to be indicated:
① main ratings of motors, transformers, batteries, electrical and electronic equipment;
② type, cross-sectional area and current loadings of cables;
③ type and main rating of circuit breakers and fuses;
④ earth fault monitoring.

(18) Arrangement of control positions and stations of electrical propulsion machinery.

(19) List of monitoring and alarm items for electrical propulsion.

(20) Arrangement of semiconductor converters, including cooling system, for electrical propulsion system.

(21) Calculations of harmonic distortion for all main connectors, including main switchboards and distribution boards, in the electrical system of electrically propelled ships.

(22) Electrical system and general arrangement of water level detection systems for cargo holds, ballast tanks and dry spaces of bulk carriers.

(23) All electrical equipment located in hazardous areas together with the following associated information are to be included in their arrangement plan:
① type of protection, explosion group and temperature class;
② degree of protection;
③ hazardous classification of the area where the electrical equipment is installed.

(24) Verification information[①] of intrinsically safe circuits, including the verification of the voltage, current, inductance and capacitance.

1.1.3.2 The specifications for all electrical systems of the ship may be submitted for information and additional plans and documents may be required as deemed necessary.

1.1.4 Testing

1.1.4.1 Electrical equipment specified in 1.1.1.2 and 1.1.2.1(1) of this Section is to be tested in accordance with the requirements of Chapter 3 of this PART at the manufacturer. Tests other than those specified in this PART may be required as deemed necessary.

1.1.4.2 On completion of installation on board, the electrical installations are to be subject to mooring and sea trials in accordance with the test programmes approved by ISC.

---

① The maximum inductance and capacitance which are the total of the cable out to the hazardous area plus the values of connected equipment are to be less than the rated values of associated apparatus. The values of permissible input voltage, input current of each intrinsically safe apparatus is to be greater than or equal to the values respectively of the associated apparatus. Refer to IEC publication 60079-14: "Explosive atmosphere-Part 14: Electrical installations design, selection and erection" or equivalent standards.

Section 2 OPERATING CONDITIONS

1.2.1 Environmental conditions

1.2.1.1 Unless otherwise specified (e.g. in 1.2.1.2 of this Section), all electrical installations are to operate satisfactorily under the following environmental conditions:

(1) The ambient air temperatures and primary cooling water temperatures are as given in Table 1.2.1.1(1), however the upper limit of ambient air temperatures for the electronic equipment is to be 55℃.

Ambient Temperature **Table 1.2.1.1(1)**

Medium	Location	Temperature (℃)	
		Unrestricted service	Restricted service except in tropical zones
Air	In enclosed spaces	0 ~ 45	0 ~ 40
	In spaces subject to temperatures over 45℃(or 40℃) or below 0℃	According to temperatures in such spaces	According to temperatures in such spaces
	On the open deck	-25 ~ 45	-25 ~ 40
Water		32	25

(2) The inclination and roll of the ship is as given in Table 1.2.1.1(2).

Angle of Inclination **Table 1.2.1.1(2)**

Installations, components	Angle (°) ①②			
	Athwartships		fore-and-aft	
	Static	Dynamic	Static	Dynamic
Emergency power installations, switchgear, electrical and electronic appliances	22.5	22.5	10	10
Electrical installations excluding items stated above	15	22.5	5	7.5

Notes: ① Athwartship and fore-and-aft inclinations may occur simultaneously.

② For ships carrying liquefied gases or chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

(3) The vibration and shock likely to arise in normal service of the ship.

(4) Moisture, sea air, oil vapour and mould.

1.2.1.2 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable may be reduced from 45℃ to a value not less than 35℃ provided:

(1) the equipment is not for use for emergency services;

(2) temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature;

(3) the equipment is able to be initially set to work safely within a 45℃ ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45℃ ambient temperature;

(4) audible and visual alarms are provided, at a continually manned control station, to indicate any malfunction of the cooling units;

(5) it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.2.2 Voltage and frequency variations

1.2.2.1 The electrical equipment supplied from the main or emergency systems is to be capable of operating satisfactorily under normally occurring variations in voltage and frequency.

1.2.2.2 Unless otherwise stated in international standards, electrical equipment is to operate satisfactorily with the variations in voltage and frequency from the rated value shown in Table 1.2.2.2 (measured at input terminals of the equipment).

Voltage and Frequency Variations **Table 1.2.2.2**

Equipment	Parameters	Permanent (%)	Transient	
			%	Max. recovery time (s)
General AC equipment	Voltage	+6 ~ -10	±20	1.5
	Frequency	±5	±10	5
Direct current equipment supplied by DC generators or rectifiers	Voltage	±10	–	–
	Voltage cyclic variation deviation	5	–	–
	Voltage ripple	10	–	–
Equipment supplied by batteries: Connected to batteries during charging① Not connected to the batteries during charging	 Voltage Voltage	 +30 ~ -25 +20 ~ -25	–	–

Note: ① Different voltage variations as determined by the charging/discharging characteristics, including the ripple voltage from the charging device, are to be considered.

1.2.2.3 Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in Table 1.2.2.2 is not to be supplied directly from the system but by alternative means, e.g. through a stabilized supply.

1.2.3 Harmonic content

1.2.3.1 AC electrical equipment is to operate satisfactorily with a supply voltage containing a total harmonic content of the voltage waveform not exceeding 8%. Where the harmonic content may exceed 8%, attention is to be given in selecting the equipment to ensure its normal function.

Section 3 DESIGN, CONSTRUCTION AND INSTALLATION

1.3.1 General requirements

1.3.1.1 Electrical equipment is to be so designed, constructed and installed as to ensure safe operation and facilitate inspection and repair.

1.3.1.2 The distance between live parts of different potential and between live parts and earthed metal, whether across surfaces or in air, is to be adequate for the working voltage, having regard to the nature of the insulating material and the conditions of service.

1.3.1.3 Equipment is not to remain alive through the control circuits or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

1.3.1.4 All nuts and screws used for the connection and fastening of electrical equipment are to be provided with means to ensure that they cannot work loose by vibration and shock.

1.3.1.5 The material used to make electrical equipment is to comply with the following requirements:

(1) It is, in general, to be durable, flame-retardant, moisture resistant unless it is adequately protected against the atmospheric environment and temperatures to which it is likely to be exposed.

(2) Insulating materials and insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect them.

(3) The current carrying parts of electrical equipment are, in general, to be made of copper or copper alloys.

(4) Metal parts of electrical equipment are to be covered with proper protective coating against corrosion unless they are made of satisfactory corrosion-resistant material.

(5) New installation of materials which contain asbestos is to be prohibited.

1.3.1.6 If electrical fittings, not of aluminium, are connected to aluminium, suitable means is to be taken to prevent electrolytic corrosion.

1.3.1.7 All electrical equipment with internal wiring is to be attached with schematic or wiring diagrams in which wiring codes are indicated. All terminals of electrical equipment are to be provided with durable markings or symbols corresponding to those indicated in the diagrams.

1.3.1.8 The controls for emergency alarms are to be marked in red and provided with durable nameplates indicating their purposes.

1.3.1.9 For the fitting of rheostats, starting and charging resistors, heating appliances and other electrical apparatus likely to cause high temperatures, means are to be provided against overheating or igniting of adjacent objects.

1.3.1.10 All electrical equipment is not to be fitted close to the external surfaces of oil compartments, oil tanks or double bottom tanks intended for carrying oils. If this is necessary, electrical equipment is to be

installed at a minimum distance of 50 mm from these surfaces, provided that the electrical apparatuses mentioned in 1.3.1.9 are strictly prohibited to be installed on such surfaces.

1.3.1.11 Generating sets are to be installed with their shafts in parallel with the fore-and-aft direction of the ship, and horizontal motors are also to be installed, as far as practicable, with their shafts in parallel with the fore-and-aft direction of the ship.

1.3.1.12 For the electrical equipment other than that installed in a dedicated compartment, the live parts having a working voltage or a voltage to earth exceeding 50 V are to be so protected that they cannot be inadvertently touched.

1.3.1.13 Where the temperature of the enclosures of the electrical equipment is in excess of 80°C, suitable means are to be provided or suitable arrangement is to be made so as to protect the operators from injurious heating due to inadvertent touching.

1.3.1.14 Holes are not to be drilled in watertight bulkheads, decks or boundary plating of deckhouses for the purpose of fitting the screws used to securing the electrical equipment and cables.

1.3.1.15 Electrical equipment and cables are not to be fitted on the shell plating.

1.3.1.16 Conductors and equipment are to be placed at a suitable distance from the magnetic compass, or are to be so screened that the interfering external magnetic field is negligible.

1.3.2 Protective enclosures

1.3.2.1 The type of protective enclosures for electrical equipment is to comply with IEC Publication 60529: Degrees of Protection Provided by Enclosures (IP Code) or equivalent standards.

1.3.2.2 The type of protective enclosures selected for electrical equipment is to be appropriate to the condition of the location at which such equipment is installed. The lowest degree of protection is to comply with the requirements given in Table 1.3.2.2 unless otherwise specified (e.g. in 1.3.2.3 and 1.3.2.4 of this Section).

Minimum Requirements for the Degree of Protection by Enclosure **Table 1.3.2.2**

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Dry accommodation spaces	Danger of touching live parts only	IP20	×	–	×	×	×	×	×	×
Dry control rooms			×	–	×	×	×	×	×	×
Control rooms	Danger of dripping water and/or moderate mechanical damage	IP22	×	–	×	×	×	×	×	×
Engine and boiler rooms above floor plates			×	×	×	×	×	×	×	IP44
Steering gear rooms			×	×	×	×	×	×	–	IP44
Refrigerating machinery rooms (excluding ammonia plants)			×	–	×	×	×	×	–	IP44
Emergency machinery rooms			×	×	×	×	×	×	–	IP44
General storage rooms			×	–	×	×	×	×	–	×
Pantries			×	–	×	×	×	×	×	IP44
Provision rooms			×	–	×	×	×	×	–	×
Bathrooms and showers	Increased danger of water and/or mechanical damage	IP34	–	–	–	–	×	IP44	–	IP55
Engine and boiler rooms below floor plates			–	–	IP44	–	×	IP44	–	IP55
Closed fuel oil separator rooms			IP44	–	IP44	–	×	IP44	–	IP55
Closed lube oil separator rooms			IP44	–	IP44	–	×	IP44	–	IP55

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Ballast pump rooms	Increased danger of water and mechanical damage	IP44	×	–	×	×	IP34	×	–	IP55
Refrigerated rooms			–	–	×	–	IP34	×	–	IP55
Galleys and laundries			×	–	×	×	IP34	×	×	×
Shaft or pipe tunnels in double bottom	Danger of water spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	IP55	×	–	×	×	×	×	–	IP56
Holds for dry cargo			–	–	–	–	×	–	–	×
Open decks	Danger of water ingress in massive quantities	IP56	×	–	×	–	IP55	×	–	×

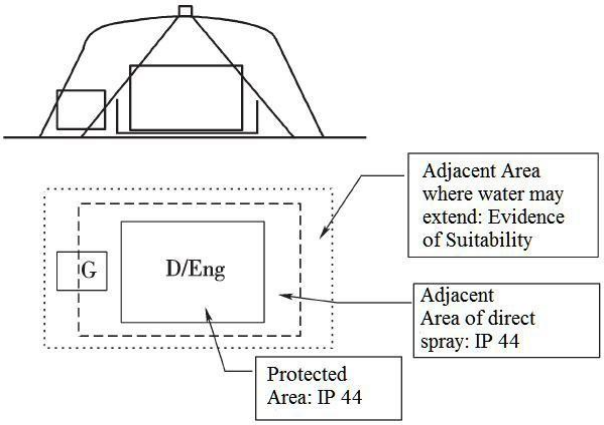
Notes: ① "×" means that the requirements of column (3) are to be complied with, or if impossible, the requirements of note ② are to be satisfied; "–" means that such equipment is generally not to be installed.

② Where the protection is not achieved by the equipment itself, other means are to be taken or the condition of the location for installing the equipment is to be improved to ensure the degree of protection required in the Table.

③ Where electrical equipment is installed in areas where explosive dusts may be present, the requirements of 1.3.3.7 of this Section are to be complied with.

④ Where the main and emergency switchboards are constructed and installed in accordance with the requirements of Section 3 of Chapter 3 and Sections 1 and 2 of Chapter 2 of this PART respectively, the requirements of this Table may be dispensed with.

1.3.2.3 In the engine room, the electrical and electronic equipment located within areas protected by fixed water-based local fire-fighting systems and those within adjacent areas exposed to direct spray (see Figure 1.3.2.3) are to have a degree of protection not less than IP44, except where evidence of suitability is submitted to and approved by ISC.



G – generator; D/Eng – diesel engine

Figure 1.3.2.3 Areas Protected by Fixed Water-Based Local Application Fire-Fighting Systems

1.3.2.4 In the engine room, the electrical and electronic equipment within adjacent areas where water may extend and which are not covered by 1.3.2.3 above (see Figure 1.3.2.3) may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, cooling airflow for the equipment is to be assured.

1.3.3 Explosion protection

1.3.3.1 Where electrical equipment is installed in areas where explosive gas or vapour atmospheres may be present, it is to be of a certified safe type complying with the following requirements:

(1) The construction and type testing of the safe type electrical equipment is to be in accordance with the relevant acceptable standards①.

(2) The safe type electrical equipment is to be certified by a competent testing authority approved by ISC.

1.3.3.2 The certified safe type equipment normally used on board ships includes the following types of protection:

(1) Intrinsically safe Ex “i”;
(2) Flameproof Ex “d”;
(3) Increased safety Ex “e”;
(4) Pressurized enclosure Ex “p”;
(5) Special protection Ex “s”;
(6) Powder filled Ex “q”;
(7) Encapsulated Ex “m”.

1.3.3.3 The electrical equipment allowed to be fitted in spaces subject to an explosion hazard, e.g. battery rooms, lamp stores and paint lockers (including ventilation ducts), is to comply with the following requirements:

(1) The electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services. Such equipment is to be of a certified safe type listed in 1.3.3.2(1) to (5) of this Section. For other spaces, the electrical equipment of certified safe types listed in 1.3.3.2 of this Section may be fitted, and the explosion groups and temperature classes of such equipment are at least to comply with the requirements in Table 1.3.3.3.

(2) Cables (through runs or terminating cables) of armoured type or installed in metallic conduits are to be used.

(3) The switches, protective devices and motor control gear for the electrical equipment installed in such spaces are to interrupt all poles or phases and preferably are to be located in non-hazardous spaces.

In addition, the relevant requirements for paint locker ventilation openings, battery rooms, oil tankers and ships carrying vehicles with fuel in their tanks for their own propulsion are given in 1.3.3.4, 1.3.3.5 of this Section, and Sections 11, 16 and 17 of Chapter 2.

---

① Refer to IEC publication 60079: Electrical Apparatus for Explosive Gas Atmospheres, or an equivalent national standard. e.g., GB 3836: Electrical Apparatus for Explosive Gas Atmospheres.

Explosion Group and Temperature Class **Table 1.3.3.3**

Location	Group①	Temperature class①
Battery rooms	II C②	T1
Paint lockers	II B	T3
Lamp stores	II A	T3
Ammonia plant rooms③	II A	T1
Acetylene storage rooms	II C	T2
Spaces carrying dangerous goods	According to the category of dangerous goods carried	According to the category of dangerous goods carried
Tunnels for pipes containing oil with a flash point of 60℃ or below	II A	T3

Notes: ① The explosion groups and temperature classes of electrical equipment listed in this Table and hereinafter in this PART are according to the relevant requirements of IEC Publication 60079: Electrical Apparatus for Explosive Gas Atmospheres or of GB 3836: Electrical Apparatus for Explosive Atmospheres.

② Explosion groups II A, II B and II C of electrical equipment listed in this PART are applicable only to intrinsically safe apparatus and flame-proof apparatus. For other types of explosion-proof electrical equipment, Group II is to be used.

③ Electrical equipment installed in R717 refrigerator room is to comply with the requirements in Section 5 of Chapter 2 of PART FIVE of the Rules.

1.3.3.4 In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets of the paint locker, the following electrical equipment may be installed:
(1) certified safe type equipment listed in 1.3.3.2(1) to (5) of this Section, while cables and their installation are to comply with the requirements of 1.3.3.3(2);
(2) explosion-proof equipment of non-sparking construction (Ex "n");
(3) appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature;
(4) appliances with simplified pressurized enclosures or vapour-proof enclosures (minimum degree of protection IP55) whose surface does not reach unacceptably high temperature.

1.3.3.5 The enclosed spaces giving access to the paint locker may be considered as non-hazardous, provided that:
(1) the door to the paint locker or the door of the paint locker is a gastight door with self-closing devices (a watertight door may be regarded as a gastight door) without holding back arrangements;
(2) the paint locker is provided with an acceptable, independent, natural ventilation system ventilated from a safe area;
(3) warning notices are fitted adjacent to the paint locker entrance stating that the locker contains flammable liquids.

1.3.3.6 Socket outlets are, unless expressly specified otherwise, not to be installed in spaces subject to an explosion hazard.

1.3.3.7 Where electrical equipment is to be installed in areas where explosive dusts may be deposited, it is to comply with the following requirements:
(1) the degree of protection by enclosures is to be at least IP55;
(2) the maximum surface temperature of the equipment in continuous service is to be at least 75 K lower than the glow temperature of a 5 mm thick layer of the dust.

1.3.4 Earthing

1.3.4.1 All accessible metal parts of the electrical equipment, other than current-carrying ones, are to be earthed, except for:
(1) lamp caps;
(2) shades, reflectors and guards supported on lamp holders or lighting fittings constructed of, or shrouded in, non-conducting material;
(3) metal parts on, or screws in or through, non-conducting material, which are separated by such material from current-carrying parts and from earthed non-current-carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(4) portable appliances having double and/or reinforced insulation, provided that the appliances conform with recognized safety requirements;
(5) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(6) clips for fluorescent lamps;
(7) apparatus supplied at a working voltage not more than 50 V. For the alternating current, this voltage is a

value of root mean square. Autotransformers are not to be used for the purpose of achieving this voltage;
(8) cable clips.

1.3.4.2 When the electrical equipment is directly fixed on the metal hull of the ship or securely fixed on bedplates (or supports) which have a good electrical contact with the metal hull of the ship, a special earthing conductor may not be required.

1.3.4.3 Whether the earthing is achieved through a special conductor or by bedplates (or supports) of the equipment, the surfaces in contact are to be clean, flat and bright so as to ensure an effective contact, and measures are to be taken to prevent the connection from loosening and corrosion.

1.3.4.4 When special earthing conductors are used, they are to be of copper or other corrosion-resistant materials of good conductivity, and are to be protected against mechanical damage and corrosion where necessary. The nominal cross-sectional area of various copper earthing conductors is not to be less than required in Table 1.3.4.4.

1.3.4.5 Bare metal parts of movable or portable appliances, other than current-carrying ones, are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket outlet, and the cross-sectional area of the earth conductor is to comply with the requirements of Table 1.3.4.4.

Size of Earthing Conductors **Table 1.3.4.4**

Type of earthing conductor	Cross-sectional area of associated current-carrying conductor S (mm^2)	Minimum cross-sectional area of copper earthing conductor Q (mm^2)
Earth-continuity conductor in flexible cable or flexible cord	$S \leq 16$	$Q = S$
	$S > 16$	$Q = S/2$, but at least 16
Earth-continuity conductor incorporated in fixed cable	$S \leq 16$	$Q = S$, but at least 1.5
	$S > 16$	$Q = S/2$, but at least 16
Special fixed earthing conductor	$S \leq 2.5$	$Q = S$, but at least 1.5
	$2.5 < S \leq 120$	$Q = S/2$, but at least 4
	$S > 120$	$Q = 70$

1.3.4.6 Metal coverings (braid or armour) of cables are to be effectively earthed at both ends of the run, except that final sub-circuits may be earthed at the supply end only. This does not necessarily apply to control and instrumentation cables or intrinsically safe circuit cables where single point earthing is permitted for technical or safety reasons.

1.3.4.7 The metal coverings of cables may be earthed by one of the means described below:
(1) gripped by metal clamps and connected to the metal hull of the ship by dedicated copper earthing conductors. The relationship between the cross-sectional area Q of the copper earthing conductors and the cross-sectional area S of the current-carrying conductors of the cables is to comply with Table 2 in IEC 60092-352 or as follows:

$Q \geq 1.5$ mm^2, for $S \leq 25$ mm^2;
$Q \geq 4$ mm^2, for $S > 25$ mm^2;

(2) by means of glands intended for this purpose and so designed as to ensure an effective earth connection;
(3) by means of clamps or clips of corrosion-resistant metal, enabling a good contact between the metal coverings of cables and the earthed metal.

1.3.4.8 The electrical continuity of metal coverings of cables is to be ensured throughout the length of the cables, particularly at joints and tappings.

1.3.4.9 Every connection of an earth-continuity conductor or a special earthing conductor to the hull structure is to be made in an accessible position, and is to be secured by a screw of brass or other corrosion-resistant material and having a diameter not less than 4 mm, which is to be used for this purpose only.

1.3.4.10 Where aluminium superstructures are secured to the steel hull of a ship with an insulation to prevent electrolytic corrosion between these materials, a separate bonding connection is to be provided between the superstructure and the hull which is to be made in such a manner that electrolytic corrosion is prevented and the connection points may readily be inspected.

1.3.4.11 In order to avoid the hazard of an incentive discharge due to the build-up of static electricity resulting from the flow of liquids/gases/vapours, all cargo tanks, process plants and piping systems that contain flammable liquids, evolve combustible gases and/or develop flammable dusts are to comply with the following requirements:
(1) The resistance between the above cargo tanks, process plants and piping systems and the hull of the ship is not to be greater than 1 MΩ.
(2) The requirements of 1.3.4.11(1) will be readily met without the use of bonding straps where cargo tanks,

process plants and piping systems are directly or via their supports, either welded or bolted to the hull of the ship.

(3) Bonding straps are required for cargo tanks, process plants and piping systems which are not permanently connected to the hull of the ship, e.g.:

① independent cargo tanks;

② cargo tanks and piping systems which are electrically separated from the hull of the ship;

③ pipe connections arranged for the removal of spool pieces;

④ wafer-style valves with non-conductive (e.g. PTFE) gaskets or seals.

(4) Where bonding straps are required, they are to be:

① clearly visible so that any shortcomings can be clearly detected;

② designed and sited so that they are protected against mechanical damage and that they are not affected by high resistivity contamination, e.g. corrosive products or paint;

③ easy to install and replace.

(5) Bonding straps are to be made of copper or other corrosion-resistant materials of good conductivity, having a cross-sectional area of at least 10 mm^2.

1.3.5 Electromagnetic compatibility

1.3.5.1 Appropriate measures are to be taken to reduce the interference due to electromagnetic energy so that all electrical and electronic equipment can operate normally in a ship's electromagnetic environment.

1.3.5.2 The allowable value of the voltage (current) of the interference induced by electrical and electronic equipment and the means of interference suppression are to comply with the relevant provisions of acceptable standards①.

1.3.6 Visual and audible signals

1.3.6.1 Except those required in 1.3.6.2 of this Section, the colour of visual signals is to comply with the requirements of Table 1.3.6.1.

1.3.6.2 Except those required above, the visual and audible signals are to comply with the acceptable standards②.

Colours of Visual signals **Table 1.3.6.1**

Colour	Meaning	Explanation	Example
Red	Danger or alarm	Warning of danger or a situation which requires immediate action	Operation failure of essential services; Temperature or pressure of water, oil etc. reaching a critical value; Power failure of essential circuits
Yellow	Caution	Change or impending change of conditions	Temperature or pressure is abnormal, but not reaching a critical value
Green	Safety (normal operating or normal working conditions)	Indication of a safe situation	Normal operation of machinery; Normal circulation of liquids; Pressure, temperature and currents within limits
Blue	Instruction/information (specific meaning assigned according to the need in the case considered)	Blue may be given a meaning which is not covered by the three above colours: red, yellow and green	Motor begins to start; Unloading generator begins to switch on; Heating circuit of stopping motor is connected
White	No specific meaning assigned	Any meaning, used if red, yellow or green is considered not applicable	Earthing insulation indication; Synchronizing lamp; Telephone calling; Automated equipment

1.3.7 Harmonic Distortion for Ship Electrical Distribution System including Harmonic Filters③

1.3.7.1 Ships where harmonic filters are installed on main busbars of electrical distribution system are to meet the requirements of 1.3.7.2 to 1.3.7.6 below. However, harmonic filters installed for single application frequency drives such as pump motors and harmonic filters installed for enhancing electromagnetic compatibility of single equipment/system may be excluded from these requirements.

1.3.7.2 The total harmonic distortion (THD) of electrical distribution systems is not to exceed 8%. This

---

① Refer to IEC Publication 60533: Electromagnetic Compatibility of Electrical and Electronic Installations in Ships, or corresponding standards.

② Refer to Code on Alerts and Indicators, 2009 adopted by IMO resolution A.1021(26).

③ Applicable to new ships and ships where an application for a periodical or occasional machinery survey after the retrofit of harmonic filters is dated on or after 1 July 2017.

limit may be exceeded where all installed equipment and systems have been designed for a higher specified limit and the harmonic distortion calculation report is to be provided and made available on board as a reference for the surveyor at each periodical survey.

1.3.7.3 Ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar as well as alerting the crew should the level of harmonic distortion exceed the acceptable limits. Where the engine room is provided with automation systems, this reading is to be logged electronically, otherwise it is to be recorded in the engine log book for future inspection by the surveyor.

1.3.7.4 The system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced. The system integrator of the distribution system is to provide the ship owner with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters. The calculation results and validity of the guidance provided are to be verified by the surveyor during sea trials.

1.3.7.5 A harmonic filter is to be arranged as a three-phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter. Additionally, a current unbalance detection system independent of the overcurrent protection alerting the crew in case of current unbalance is to be installed. This alarm is to be provided locally and/or in normally attended spaces.

1.3.7.6 Consideration is to be given to additional protection for the individual capacitor element (e.g. relief valve or overpressure disconnector) in order to protect against damage from rupturing. This consideration is to take into account the type of capacitors used.

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

2.1.1 Generating sets

2.1.1.1 A main source of electrical power having sufficient capacity to supply all services mentioned in 1.1.1.5(1) of this PART is to be provided, and the following requirements are to be complied with.

(1) The main source of electrical power is to consist of at least two generating sets.

(2) The number and ratings of these generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety of the ship and essential for ships with class notation for carrying refrigerated cargoes as specified in PART FIVE of the Rules. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

(3) The generating sets are to be such as to ensure that with any one generator or its prime mover out of operation, the remaining generating sets are still capable of providing the electric services necessary to start the main propulsion plant from a dead ship condition.

(4) Where the main source of electrical power is necessary for propulsion and steering of the ship, the continuity of the power supply to the equipment necessary for the propulsion and steering and for ensuring the safety of the ship is to comply with the following requirements:

① Where the electrical power is normally supplied by more than one generating set simultaneously in parallel operation, means of protection, including automatic shedding (see 2.5.7.1 of this Chapter) of non-essential services and if necessary, automatic shedding of the arrangements for habitability and secondary essential services, are to be provided to ensure that in case of loss of any of these generating sets, the remaining ones are kept in operation to supply equipment necessary for propulsion and steering and for ensuring the safety of the ship.

② Where the electrical power is normally supplied by one generator, provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of a stand-by generator(s) of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of the stand-by generator is to be as rapid as possible, preferably within 30 s, but in any case not more than 45 s, after loss of power.

(5) Where the main source of electrical power is necessary for propulsion of the ship, the main bus-bar is to be subdivided into at least two independent sections which are normally be connected by a circuit breaker without tripping mechanism or disconnecting link or switch by which the bus-bar can be split easily. So far as is practicable, the connection of generating sets and other duplicated equipment is to be equally divided between the sections.

(6) A common power plant may be provided as both the main source of electrical power and the electrical power for propulsion, and in this case the requirements of 15.2.1.9 of Chapter 15, PART EIGHT of the Rules are to be complied with.

2.1.1.2 The alternating current system is to be such that with one generating set out of action, the remaining sets have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any other device to fail due to excessive voltage drop on the system. Motors which have a very large capacity and are not essential to the safe navigation of the ship, such as thruster motors, may be started when all generators are put into operation without causing any essential services to stop.

2.1.1.3 The arrangement of the ship's main source of electrical power is to be such that the operation of the services referred to in 1.1.1.5(1) of this PART can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.1.1.4 For calculation of the capacity of generating sets, where the detailed power of refrigerated containers can not be provided, it is recommended that 11 kW be taken for each socket where the sockets of refrigerated containers are adaptable to power supply for 20 ft or 40 ft containers. It is also recommended that 7.5 kW be taken for each socket suitable only for power supply of 20 ft containers. A diversity factor of 0.6 may be taken for calculation of loading of containers.

2.1.1.5 A main source of electrical power may be provided as necessary for non-self-propelled ships. Where the main source of electrical power is the generator, the provisions of 2.1.1.1 to 2.1.1.3 of this Chapter need not be complied with.

2.1.2 Generators driven by main propulsion machinery (e.g. shaft-driven generators)

2.1.2.1 A generator driven by the ship's main propulsion machinery may be considered part of the ship's main source of electrical power, provided that:
(1) the generator is capable of operating normally under all weather conditions during sailing or maneuvering, also when the vessel is stopped, within the specified limits for the voltage variation in paragraphs 3.2.7 and 3.2.8 and for the frequency variation in 1.2.2.2;
(2) the rated capacity of the generator is in compliance with 2.1.1.1(2) upon loss of any other generator in service;
(3) the short circuit current of the generator and/or generator system is sufficient to trip the generator circuit breaker, taking into account the selectivity of the protective devices for the distribution system. Protection is to be arranged in order to safeguard the generator in case of a short circuit in the main bus-bar. The generator is to be suitable for further use after fault clearance;
(4) the automatic start of standby sets is in compliance with 2.1.1.1(4)②.
2.1.2.2 A generators and/or generating system driven by the ship's propulsion machinery and not forming part of the ship's main source of electrical power may be used, whilst the ship is at sea, to supply the electrical equipment necessary for normal operational and habitable conditions provided that:
(1) sufficient and adequately rated additional generators are fitted, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section;
(2) arrangements are fitted to automatically start at least one of the generators, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section, in compliance with 2.1.1.1(4)②, when frequency variations exceed the limits specified below:
Frequency variations (permanent): ±5.5%
Frequency variations (transient): ±11% (5 s);
(3) voltage variations are within the limits specified in 3.2.7 and 3.2.8 and frequency variations within the limits specified in 1.2.2.2;
(4) the short circuit current of the generator and/or generating system is sufficient to trip the generator and/or generating system circuit breaker, taking into account the selectivity of the protective devices for the distribution system;
(5) automatic load shedding arrangements are fitted in accordance with the requirements of 2.5.7 of this Chapter;
(6) on ships having remote control of the propulsion machinery from the navigation bridge, means are provided or procedures are in place to ensure that the power supply to essential services is maintained during maneuvering conditions in order to avoid a blackout situation.

2.1.3 Transformers

2.1.3.1 The number, capacity and arrangement of transformers are to meet the following requirements if they constitute the necessary parts of lighting system and main electric power source system as required in 2.1.1.1 of this Section.
(1) The transformers are to be such that, with any one transformer out of operation, the remaining transformers are sufficient to ensure the safe operation of the equipment necessary for normal propulsion and for safety of the ship. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.
(2) Each transformer is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides.
(3) Each primary circuit is to be provided with switch gear and protection devices in each phase.
(4) Each of the secondary circuits is to be provided with a multi-pole isolating switch.

2.1.4 Installation of switchboards

2.1.4.1 The main switchboard is to be so placed relative to the main power plant that, as far as is practicable, the integrity of the normal electrical supply will be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating the switchboard from the generators.
2.1.4.2 Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the switchboard. If this is unavoidable, suitable protection is to be provided in these positions.
2.1.4.3 Passages of an adequate width are to be left in front of and behind switchboards. The width of the front passage is to be at least 0.8 m. The width of passage behind the switch gear is to be at least 0.6 m, and at least 0.5 m at frames. If the construction of a switchboard is such as to permit maintenance, inspection and replacement of parts from the front or from the ends, the passageway behind the switchboard may be

dispensed with.
2.1.4.4 Where the length of the main switchboard is greater than 4 m, passageways are to be, as far as possible, provided at both ends of the switchboard. Except that the main switchboard is installed in the machinery control room, doors with locking devices are to be provided at both ends of the passageway behind the switchboard.
2.1.4.5 The passageways in front of and behind the main switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.1.5 Automatic connecting and disconnecting of main generating set

2.1.5.1 Requirements of paragraph 2.1.5.2 to 2.1.5.6 are to be met where start, stop and load sharing between generators, is controlled by an automation system.
2.1.5.2 The following alarms are to be arranged:
(1) variations in bus bar voltage from the rated value (high and low);
(2) variations in bus bar frequency from the rated value (high and low);
(3) automatic load shedding;
(4) failure in automatic switch-on of circuit breaker of generator;
(5) automatic tripping of circuit breaker of generator;
(6) failure in load distribution (with the necessary time delay, see paragraph 3.2.8.5 of Chapter 3 for the percentage of load distribution).
2.1.5.3 Means are to be provided to avoid two or more than two generating sets being switched on the common bus-bar of main switchboard simultaneously.
2.1.5.4 After a blackout due to short circuit, the generator circuit breaker is permitted to be switched on only once.
2.1.5.5 Where the standby generating set has been started as a result of a prolonged main bus-bar voltage or frequency fluctuation, the running generating set is to be stopped and disconnected from the switchboard prior to connection of the standby generating set.
2.1.5.6 Automatic starting attempts which fail are to be limited to restrict consumption of starting energy.

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

2.2.1 General requirements

2.2.1.1 All passenger ships and cargo ships of more than 500 gross tonnage are to be provided with a self-contained emergency source of electrical power.
2.2.1.2 The emergency source of electrical power is to be so arranged as to comply with the following:
(1) The emergency source of electrical power, associated transforming equipment (if any), transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and are to be readily accessible from the weather deck. They are not to be located forward of the collision bulkhead, except where permitted by ISC for cargo ships in exceptional circumstance.
(2) The location of the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment (if any), and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment (if any), and the main switchboard or in any machinery space of category A will not interfere with the supply, control and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency electrical power and the emergency switchboard is not to be continuous to the boundaries of machinery spaces of category A or those spaces containing the main source of electrical power, associated transforming equipment (if any), or the main switchboard.
2.2.1.3 The emergency source of electrical power may be a generator, which is to comply with the following requirements:
(1) driven by a suitable prime mover with independent cooling system and supply of fuel as well as starting arrangements complying with the requirements of 9.5.3 of Chapter 9, PART THREE of the Rules;
(2) started automatically upon failure of the electrical supply from the main source of electrical power and connected automatically to the emergency switchboard, and those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section then transferred automatically to the emergency generating set, except for cargo ships fitted with a transitional source of emergency electrical power in

accordance with 2.2.1.5 of this Section. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.

2.2.1.4 The emergency source of electrical power may also be an accumulator battery, which is to comply with the following requirements:

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(3) supplying those services (except as otherwise stated) referred to in 2.2.2.1 (for passenger ships) or 2.2.3.1 (for cargo ships) of this Section, and immediately supplying those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.5 Where the emergency source of electrical power is a generator, a transitional source of emergency electrical power which consists of an accumulator battery is to be provided in compliance with the following requirements, except for cargo ships fitted with an emergency generator capable of automatic starting in accordance with 2.2.1.3(2):

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) so arranged as to supply immediately and automatically in the event of failure of either the main or emergency source of electrical power those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.6 Where the emergency source of electrical power is required to restore propulsion from a dead ship condition, the capacity is to be sufficient to supply the following equipment within 30 min of the blackout (For steam turbine ships, the 30-min time limit is to be taken as the time from blackout/dead ship condition to light-off of the first boiler):

(1) equipment referred to in 2.2.2.1(1), (2) and (3) or in 2.2.3.1 (1), (2), (3) and (4) of this Section;

(2) restoring propulsion of the ship and operation of other machineries (as appropriate) from a dead ship condition.

2.2.1.7 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power and to comply with the following requirements:

(1) Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

(2) Where the emergency source of electrical power is an accumulator battery, the accumulator battery is not to be installed in the same space as the emergency switchboard.

(3) Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the emergency switchboard. If this is unavoidable, suitable protection is to be provided in these positions.

(4) The passageways in front of the emergency switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.2.1.8 An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or transitional source of emergency electrical power are being discharged.

2.2.1.9 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected according to the requirements of 2.5.9.6 and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

2.2.1.10 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power is to be available to the emergency circuits.

2.2.1.11 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

2.2.1.12 Where the emergency and/or transient emergency source of electrical power is an accumulator battery which supplies emergency loads via an electronic converter or inverter, the maximum permitted D.C voltage variations (taken as those on the load side of the converter or inverter) are to be within 12% above or below its nominal voltage; where DC is converted into AC the maximum variations are to comply with Table 1.2.2.2.

2.2.1.13 UPS units utilizing valve regulated sealed batteries, as described in 2.2.2.1 and 2.2.3.1 of this Section, may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC

62040-4 and/or IEC62040-5-3 publication (where applicable) or an acceptable standard.

2.2.2 Scope and period of supply of the emergency source in passenger ships

2.2.2.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 36 h, emergency lighting:

① at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;

② in alleyways, stairways and exits giving access to the muster and embarkation stations as required in the SOLAS Convention in force;

③ in all escape routes with their stairways and exits (including angles and intersections) placed not more than 0.3 m above the deck as required in the SOLAS Convention in force (where an emergency source of electrical power is required for the supply);

④ in all service and accommodation alleyways, stairways and exits, personnel lift cars;

⑤ in public spaces and in cabins accommodating more than 16 persons;

⑥ in the machinery spaces and main generating stations including their control positions;

⑦ in all control stations, machinery control rooms, and at each main and emergency switchboard;

⑧ at all stowage positions for firemen's outfits;

⑨ at the steering gear; and

⑩ at the fire pump, the sprinkler pump and the emergency bilge pump referred to in the subparagraph (4) and at the starting position of their motors;

(2) for a period of 36 h:

① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;

② VHF radio equipment, MF radio installation (if any), ship earth station (if any) and MF/HF radio equipment (if any) required in the SOLAS Convention in force;

(3) for a period of 36 h:

① all internal communication equipment required in an emergency;

② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of ISC;

③ the fire detection and fire alarm system, and the fire door holding and release system; and

④ for intermittent operation of the daylight signaling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarm system, alarms for warning of the release of extinguishing media),

unless such services mentioned above in ① to ④ have an independent supply for the period of 36 h from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9, Chapter 3 of this PART suitably located for use in an emergency;

(4) for a period of 36 h:

① one of the fire pumps required in the SOLAS Convention in force;

② the automatic sprinkler pump, if any;

③ the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(5) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear if required to be so supplied by that paragraph;

(6) for a period of half an hour:

① any watertight doors required in the SOLAS Convention in force to be power operated together with their indicators and warning signals;

② the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;

2.2.2.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services, if they depend upon an electrical source for their operation:

(1) for half an hour:

① the lighting required in 2.2.2.1(1) (except for 2.2.2.1(1)③) and navigation lights and other signal lights required in 2.2.2.1(2)① of this Section;

② all services required in 2.2.2.1 (3)①, ③ and ④ unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(2) power to operate the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided;

(3) power to the control, indication and alarm circuits for operation of watertight doors for half an hour.

2.2.2.3 In addition to the emergency lighting required above, passenger ships with ro-ro cargo spaces or special category spaces are to be provided with the following:

(1) all passenger public spaces and alleyways are to be provided with supplementary emergency lighting complying with the following:

① capable of operating for at least three hours when all other sources of electrical power have failed and under any condition of heel;

② the illumination provided is to be such that the approach to the means of escape can be readily seen;

③ the source of power for the supplementary lighting is to consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, other means of lighting which is at least as effective may be accepted by ISC;

④ the supplementary lighting is to be such that any failure of the lamp will be immediately apparent;

⑤ any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;

(2) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (1) above, is provided.

2.2.3 Scope and period of supply of the emergency source in cargo ships

2.2.3.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 3 h, emergency lighting at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;

(2) for a period of 18 h, emergency lighting:

① in all services and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;

② in the machinery spaces and main generating stations including their control positions;

③ in all control stations, machinery control rooms, and at each main and emergency switchboard;

④ at all stowage positions for firemen's outfits;

⑤ at the steering gear;

⑥ at the fire pump referred to in (5), at the sprinkler pump (if any), and at the emergency bilge pump (if any), and at the starting positions of their motors;

⑦ in all cargo pump rooms of tankers;

(3) for a period of 18 h:

① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;

② VHF radio installation, MF radio installation (if any), ship earth station (if any) and MF/HF radio installation (if any) required in the SOLAS Convention in force;

(4) for a period of 18 h:

① all internal communication equipment as required in an emergency;

② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of ISC;

③ the fire detection and fire alarm system;

④ intermittent operation of the daylight signaling lamp, the ships whistle, the manually operated call

points and all internal signals that are required in an emergency (e.g. general emergency alarms system, alarms for warning of the release of extinguishing media, etc.),

unless such services mentioned above in ① to ④ have an independent supply for the period of 18 h from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9, Chapter 3 of this PART suitably located for use in an emergency;

(5) for a period of 18 h, one of the fire pumps required in the SOLAS Convention in force if dependent upon the emergency generator for its source of power;

(6) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear where it is required to be so supplied by that paragraph;

2.2.3.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services for half an hour, if they depend upon an electrical source for their operation:

(1) the lighting required in 2.2.3.1(1) and (2), and navigation lights and other signal lights required in 2.2.3.1(3)①. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(2) all services required in 2.2.3.1(4)①, ③ and ④, unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

2.2.4 Use of emergency generator in port

2.2.4.1 The emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements below are complied with:

(1) to prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation;

(2) the prime mover is to be fitted with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation;

(3) the fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in 2.2.2 or 2.2.3 of this Section;

(4) the prime mover is to be designed and built for continuous operation and to be subjected to a planned maintenance scheme verified by ISC ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea;

(5) fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed;

(6) means are to be provided to readily change over to emergency operation;

(7) control, monitoring and supply circuits, for the purpose of the use of the emergency generator in port, are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services. When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits;

(8) instructions, which are to contain information on required fuel oil tank level, position of harbor/sea mode switch, ventilation openings etc., are to be provided on board to ensure that when the vessel is under way all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard. These instructions are to be posted in the emergency generator room.

Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER

2.3.1 Shore connection system of rated voltage of 1 kV and less

2.3.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box complying with the requirements of 3.3.2.11 of this PART is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source. Suitable cables having adequate ratings, permanently fixed, are to be provided for connection between the shore connection box and the main switchboard or emergency switchboard.

2.3.1.2 When a three-phase AC system with neutral earthed is adopted for shore and/or ship power, an earth terminal is to be provided for connecting the ship's hull to shore. In the case of DC systems with hull return, the negative terminal of the shore power must be connected to hull.

2.3.1.3 The shore connection is to be provided with an indicator at the main switchboard or emergency

switchboard in order to show when the cables are energized.
2.3.1.4 Where an automatic control device is used for the connection and disconnection of shore supply, the device is to comply with the applicable requirements in Chapter 2 of PART SEVEN of the Rules.
2.3.1.5 In addition to the requirements of 2.3.1.6, an interlocking device between all main generators and emergency generators and the shore supply is to be provided to avoid simultaneous power supply.
2.3.1.6 Where the system has the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.5.3, 19.2.5.4 and 19.2.6, Chapter 19 of PART EIGHT are to be complied with.

2.3.2 Shore connection system of rated voltage above 1 kV

2.3.2.1 For the shore connection system where load transfer between the shore supply and ship power is executed via blackout, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4, 19.2.5.2 and 19.2.6 of Chapter 19, PART EIGHT of the Rules are at least to be complied with.
2.3.2.2 For the shore connection system having the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4, 19.2.5.3, 19.2.5.4 and 19.2.6 of Chapter 19, PART EIGHT of the Rules are at least to be complied with.
2.3.2.3 The shore supply equipment installed onboard the ship is to comply with the requirements of Section 3, Chapter 19, PART EIGHT of the Rules.

Section 4 POWER SUPPLY AND DISTRIBUTION

2.4.1 Power supply and distribution systems

2.4.1.1 The following systems of distribution may be used:
(1) DC
two-wire insulated system;
two-wire system with negative pole earthed;
single-wire system with negative to hull return.
(2) AC single phase
two-wire insulated system;
two-wire system with one pole earthed;
single-wire system with hull return.
(3) Three-phase AC
three-wire insulated system;
four-wire system with neutral earthed;
three-wire system with neutral earthed and the hull serving as neutral wire.
Other distribution systems than those mentioned above are to be subject to special approval by ISC.
2.4.1.2 For power supply and distribution systems for high-voltage systems, refer to the requirements of 2.14.2.1 of this PART.
2.4.1.3 For the distribution systems of ships intended for the carriage of crude oil and petroleum products in bulk having a flash point (closed-cup test) below 60°C, refer to the requirements of 2.16.2.1 of this PART.

2.4.2 Insulated distribution systems

2.4.2.1 The neutrals of generating sets are not to be connected together in the insulated distribution system.
2.4.2.2 The insulated distribution systems for power, heating and lighting circuits, whether primary or secondary, are to be provided with a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication in case of abnormally low insulation values.

2.4.3 Earthed and hull return systems of distribution

2.4.3.1 The hull return system of distribution is not to be used for power, heating or lighting in ships of 1,600 gross tonnage and upwards, but not excluding the following:
(1) impressed current cathodic protective systems;
(2) limited and locally earthed systems, provided that any possible resulting current will not directly flow through any hazardous areas;
(3) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable condition.
2.4.3.2 Where the hull return system is used, all final sub-circuits are to have all poles or phases insulated,

the hull return being achieved by connecting to the hull one of the bus-bars of the distribution board from which they originate.

2.4.3.3 The earthed distribution system in a high-voltage system is to be in compliance with the relevant requirements of 2.14.2.1 of this PART.

2.4.3.4 The earthing conductors used in the hull return system are to be of the same cross-sectional area as the conductors in the insulated pole or phase, and bare conductors are not to be used.

2.4.3.5 Enclosures of equipment or their mounting bolts are not to be used as return conductors or connection to the conductors.

2.4.3.6 The cross-sectional area of earthing conductors which do not normally carry current in service is to be 50% of that of the current-carrying conductors, but not less than 1.5 mm^2.

2.4.3.7 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current-carrying parts of the electrical equipment.

2.4.4 Voltage and frequency

2.4.4.1 The maximum voltages of AC distribution systems are not to exceed the values given in Table 2.4.4.1.

Maximum Voltages of AC Distribution Systems **Table 2.4.4.1**

No.	Application	Max. voltage (V)
1	For power equipment permanently installed and connected by permanent wiring	15,000
2	(1) For heating and cooking equipment permanently installed and connected by permanent wiring, except space heaters. (2) For portable equipment, which is not hand-held during operation, and with connection by socket outlet which incorporates an earth continuity conductor of a size in accordance with 1.3.4.5 of this PART	1,000
3	(1) For lighting permanently installed (2) For socket outlets supplying the following (which are not specified in items 2 and 4 in the table): ① equipment with double insulation; ② equipment earthed by earth continuity conductors of a size in accordance with 1.3.4.5 of this PART	250
4	For socket outlets used in spaces where particular risks due to exposure and conductivity may exit: (1) supplied with or without the use of isolating transformers; (2) where a safety isolating transformer is used supplying one consuming device only. Both wires of such systems are to be insulated from earth	55① 250
5	Instrumentation and control equipment②	55③ 250

Note: ① For socket outlets with rated voltage up to 24V, the maximum voltage is 55V.
② For the control voltage of distribution systems operating at a voltage above 500 V, see 2.4.4.2 of this Section.
③ For instrumentation and control equipment with rated voltage up to 48V, the maximum voltage is 55V.

2.4.4.2 For distribution systems operating at a voltage above 500 V, the control voltage is to be limited to 230 V, except where all control devices of the distribution systems operating at a voltage not exceeding 1000 V are enclosed in appropriate control boxes.

2.4.4.3 The standard frequency for AC distribution systems is to be 50 Hz or 60 Hz.

2.4.4.4 The maximum voltages of DC distribution systems are not to exceed the values given in Table 2.4.4.4.

Maximum Voltages of DC Distribution Systems **Table 2.4.4.4**

No.	Application	Max. voltage (V)
1	Power equipment	1500
2	Cooking equipment, heating equipment, lighting and socket outlets	500
3	Communication equipment, instrumentation	250
4	Socket outlets supplying power for life boats/rafts	55

2.4.5 Balance of loads

2.4.5.1 For AC three-wire or four-wire systems, the electrical consumers are to be so grouped in the final sub-circuits that the load in each phase will, under normal conditions, be balanced as far as possible within 15% of its rated load at the individual distribution and section boards as well as the main switchboard.

2.4.6 Diversity factors

2.4.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.4.6.2 The diversity factor may be applied to the calculation of the cross-sectional area of conductors and the rating of switch gear and fuse gear.

2.4.6.3 For cargo winches, a diversity factor may be applied based on the information available from the manufacturer and the information agreed upon between the manufacturer and purchaser. If there is no exact information available, the diversity factors of Table 2.4.6.3 may be applied.

Diversity Factors **Table 2.4.6.3**

Number of motors	Current to be provided for	
	Cases in which motors are of the same size	Cases in which motors are of different sizes
2	100% of combined full load of motors	
3	67% of combined full load of motors	100% of full load of the largest motor + 50% of full load of each one of the other motors
4	62% of combined full load of motors	
5	60% of combined full load of motors	
6 or more	58% of combined full load of motors	

2.4.6.4 For the diversity factors of socket circuits for refrigerated containers, refer to the requirements of Chapter 4, PART FIVE of the Rules.

2.4.7 Power supply to essential services

2.4.7.1 Unless expressly provided otherwise, the primary essential services are to be supplied directly from the main or emergency switchboard (if required), except for the total discrimination.

2.4.8 Power supply to radio equipment and navigation equipment

2.4.8.1 The power supply to the radio equipment as required in Chapter IV (hereinafter referred to as the radio equipment) and the electrical/electronic navigation equipment as required in Chapter V (hereinafter referred to as the navigation equipment) of the SOLAS Convention are to comply with the requirements of 2.4.8.2 to 2.4.8.4.

2.4.8.2 The distribution board of supplies to the radio equipment is to be independent of that of supplies to the navigation equipment.

2.4.8.3 The distribution board of the radio equipment and that of the navigation equipment supplied by the emergency source of electrical power are to be supplied by separate feeders from main and emergency switchboards, and each distribution board is to be provided with a device for changing over between main and emergency sources of electrical power, which is in general to be initiated automatically. In the event of any failure of the power supply of the radio distribution board, an audible and visual alarm is to be given in the navigation bridge.

2.4.8.4 Each consumer is to be supplied by an independent final sub-circuit from its distribution board.

2.4.9 Power supply to auxiliary machinery motors, etc.

2.4.9.1 In addition to the above-mentioned requirements, the power supply to auxiliary machinery motors, illumination, navigation lights, internal communication systems and safety system for ships and persons on board is to comply with the relevant requirements of this PART.

2.4.9.2 For AC distribution systems, final sub-circuits rated over 16A are not to supply more than one equipment, except that they only supply socket outlets with current rating not greater than 32A.

2.4.10 Sockets

2.4.10.1 The sockets for general portable appliances are to be in compliance with the requirements of No.3 and No.4 in Table 2.4.4.1 of this Section.

2.4.10.2 For the sockets of distribution systems operating at different voltages and/or frequencies, non-interchangeable plugs are to be used for connection.

2.4.10.3 No socket outlets are to be provided below floor plates in machinery spaces, or in enclosed fuel

and lubrication oil separator rooms.
2.4.10.4 Where sockets are necessary in cargo holds, they are to be fitted in positions with sufficient protection against mechanical damage.
2.4.10.5 For sockets of refrigerated containers, refer to the relevant requirements of Chapter 4, PART FIVE of the Rules.
2.4.10.6 Socket outlets for power circuits rated over 16A (AC) or 10A (DC) are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

2.4.11 Power supply with transformers operating in parallel

2.4.11.1 Transformers arranged for parallel operation are to comply with the following requirements:
(1) their winding connections are to be compatible;
(2) their rated voltage ratios are to be equal (with tolerances within permissible limits);
(3) their short-circuit impedance values are to be equal (if expressed in percentage, a ratio within 0.9 to 1.1 may be allowed);
(4) when transformers are intended for operation in parallel, the rated output of the smallest transformer in the group is not to be less than 50% of the rated output of the largest transformer in the group.

2.4.12 Power supply to safety, control and alarm systems of prime movers

2.4.12.1 The prime movers referred to in this paragraph mean diesel engines, gas turbines and steam turbines, etc. that drive the electric generators which comprise the main source of electric power.
2.4.12.2 The safety, control and alarm systems of prime movers are to be supplied by two independent power sources, which and associated wiring are to be such that the requirements of 2.1.1.1(2) of this Chapter can be met in case of single failure.

2.4.13 Power supply to electronic control system of diesel engines

2.4.13.1 The power supply to electronic control systems of diesel engines is to comply with the requirements of 2.2.4 of Appendix 2 to Chapter 9, PART THREE of the Rules.

Section 5 PROTECTION

2.5.1 General requirements

2.5.1.1 Electrical installations are to be suitably protected against overcurrents including short circuits, and other electric faults. The performance and arrangement of the protective devices are to provide complete and coordinated automatic protection to ensure the continuity of supply to available essential services through the discriminative action of the protective devices in the event of a fault elsewhere, and to ensure the elimination of the effects of the fault to reduce damage to the system and hazard of fire. Coordination is to be provided:
(1) between main generator protective device, main bus-bar section breakers (if provided with trip), protective devices (if fitted) of feeders connected to the main bus-bar, and protective devices of feeders from the main bus-bar;
(2) between protective devices of feeders and branch circuits of the distribution board containing essential services, unless otherwise specified in 2.5.3.6 of this Section;
(3) between protective devices of feeders from the emergency generator and the emergency bus-bar, and between protective devices of feeders interconnecting main and emergency switchboards and feeders from the emergency bus-bar.
2.5.1.2 Short-circuit protection is to be provided in each non-earthed pole or phase of distribution systems.
2.5.1.3 Overload protection is to be provided in:
(1) insulated two-wire DC or single-phase AC systems: at least one pole or phase;
(2) insulated three-phase AC systems: at least two phases;
(3) earthed systems: each non-earthed pole or phase.
2.5.1.4 No fuse or non-linked switch is to be inserted in an earthed conductor of distribution systems.

2.5.2 Calculations of short-circuit current

2.5.2.1 In the calculation of the maximum prospective short-circuit current, consideration is to be given to:
(1) all generators which are possibly connected in parallel to reach the maximum required power;
(2) all motors which are normally simultaneously connected in the system.

2.5.2.2 When necessary, the prospective short-circuit power factor of the AC system is to be calculated. If the power factor so obtained is less than the specified one corresponding to the rated short-circuit making or breaking capacity of the selected switch gear, then the breaking capacity of such switch gear is to be reduced accordingly.
2.5.2.3 Short-circuit calculations are to be referred to Appendix 1 of this PART: Short-Circuit Current Calculations with Regard to Electrical Installations, or performed by other methods acceptable to ISC.
2.5.2.4 In general, short-circuit calculations are to be carried out for the following:
(1) short circuit at the output terminal of generators;
(2) short circuit at the main bus-bar;
(3) short circuit at the bus-bars of the emergency switchboard, section switchboards and distribution switchboards;
(4) short circuit at the secondary side of power and lighting transformers.
For the determination of the discriminative action of protective devices, short-circuit calculations are, if necessary, to be additionally performed for short-circuit at terminals of the protected circuit, when only the smallest generator is in supply.

2.5.3 Choice of protective devices against short-circuit

2.5.3.1 Protection against short-circuit currents is to be provided by fuses or circuit-breakers.
2.5.3.2 Unless otherwise specified in 2.5.3.3 and 2.5.3.5, the breaking capacity of protective devices against short-circuit is to comply with the following requirements:
(1) The rated short-circuit breaking capacity of fuses and general circuit breakers is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.
(2) The rated operating short-circuit breaking capacity (I_{cs}) of circuit breakers for relevant circuits of essential services is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated operating short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.
2.5.3.3 The rated short-time withstanding current of category B circuit breakers (with short time-lag) is not to be less than the maximum prospective short-circuit current at the instant of contact separation at the point of installation. For the AC systems, the rated short-time withstanding current is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the instant of contact separation at the point of installation.
2.5.3.4 Unless otherwise stated in 2.5.3.5 of this Section, the rated short-circuit making capacity of every circuit breaker or switch which will possibly be initiated for a short-circuit is not to be less than the maximum peak value of the prospective short-circuit current at the point of installation.
2.5.3.5 The use of a circuit-breaker having a short-circuit breaking and/or making capacity less than the maximum prospective short-circuit current at the point of installation is permitted, provided that it is backed up on the generator side by a fuse or by a circuit-breaker (not the generator circuit-breaker) having the necessary rated short-circuit breaking/making capacity.
The short-circuit performance of the back-up protective arrangement is to be at least as that required for a single circuit-breaker by a standard① acceptable to ISC. The circuit-breaker is to have the same utilization category as the circuit-breaker on the load side of the back-up arrangement and a rated short-circuit breaking/making capacity for the maximum prospective short-circuit current at the supply terminal of the arrangement.
2.5.3.6 The back-up protection complying with the requirements of 2.5.3.5 may be used for circuits of non-essential services and of duplicated essential services with automatic change-over. The same fuse or circuit-breaker may be used to back up more than one circuit-breaker when essential services are not involved.
2.5.3.7 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuse and circuit-breaker are designed for coordinated action, so as to ensure that the operation of the fuse takes place in due time to prevent arcing between poles or between poles and metal parts of the circuit breaker when they are subjected to an overcurrent involving the operation of the fuse.
2.5.3.8 When determining the short-circuit performance requirements for the above-mentioned back-up protection arrangement, the impedance of the elements of the arrangement may be taken into account, such as the impedance of a cable connection when the circuit-breaker on the load side is far away from the back-up circuit-breaker or fuse.

---

① Refer to IEC Publication 60947-2: Low-Voltage Switch Gear and Control Gear – Part 2: Circuit-Breakers.

2.5.4 Selective protection for short-circuit

2.5.4.1 Unless otherwise stated in 2.5.3.6 of this Section, the short-circuit protection of essential services is to be selective and comply with the following:

(1) to ensure that only the protective device nearest to the fault initiates disconnection of the defective circuit in the case of short-circuit;

(2) the tripping time of the protective devices connected in series is to be carefully coordinated;

(3) during the required time of selective protection, the protective device is to be capable of carrying the short-circuit current without breaking at the point of installation.

2.5.5 Choice of protective devices against overload

2.5.5.1 Circuit breakers provided for overload protection are to have a tripping characteristic (overcurrent − trip time) adequate for the overloading ability of protected elements and for any discrimination requirement of the system.

2.5.5.2 The use of fuses for overload protection is permissible up to 320 A, provided they have suitable characteristics, but the use of circuit breakers or similar devices for protection against overload above 200 A is recommended.

2.5.6 Protection of generators

2.5.6.1 Unless otherwise provided in 2.5.6.8 of this section, generators are to be protected against short-circuit and overloads by circuit breakers arranged to interrupt simultaneously all insulated poles, and the overload protection is to be adequate for the thermal capacity of the generator. In addition, the following requirements are to be complied with:

(1) for overloads between 10% and 50%, the circuit breaker is to be tripped with a time delay of less than 2 min. It is recommended that the circuit breaker be set within the limits of 125 to 135% of the rated current of the generator and with a time delay of 15 to 30 s;

(2) for overcurrents in excess of 50% but less than the steady short-circuit current of the generator, the circuit breaker is to be tripped after a short-time delay required for the discriminative protection of the system.

It is recommended that the pick-up current for tripping of the circuit-breaker after a short-time delay be set at 200% to 250% of the rated current of the generator and with a maximum time delay of 0.2 s (DC) or 0.6 s (AC);

(3) circuit breakers for three or more generators connected in parallel are also to be provided with instantaneous releases which are to be set slightly greater than the maximum short-circuit current of the generators protected so that the circuit-breaker may break instantaneously. Other equivalent means may also be accepted subject to the agreement of ISC.

2.5.6.2 For generators less than 50 kW (or kVA) in unit capacity and not arranged to operate in parallel, a multi-pole linked switch with a fuse in each insulated pole may be fitted for protection.

2.5.6.3 Generators having a capacity of 1,500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit breaker will de-excite the generator and open the circuit breaker. This does not apply to emergency generators.

2.5.6.4 AC generators arranged to operate in parallel are to be provided with a reverse-power protection, with a time delay set within 3 to 10 s. DC generators arranged for parallel operation are to be provided with instantaneous or short-time delayed (less than one second) reverse current protection. The setting of reverse power (or reverse current) protection of generators arranged for parallel operation, dependent on the type of the prime mover used, is to be as follows:

(1) for diesel engines − 8% to 15% of the rated power (or current) of the generator;

(2) for steam turbines − 2% to 6% of the rated power (or current) of the generator.

A fall of 50% in the applied voltage is not to render the reverse power (or reverse current) protection inoperative, although it may alter the amount of reverse power required to open the breaker.

For the reverse-current protection, due consideration is to be given to the reverse current resulting from the ship's network (e.g. cargo winches).

Where equalizer leads are provided, the reverse current protection is to be connected to the positive pole of DC generators.

2.5.6.5 Generators arranged to operate in parallel are to be provided with undervoltage protection as follows:

(1) the operation of undervoltage release is to be instantaneous, if used to prevent the circuit-breaker from closing when the generator is not generating electrical energy;

(2) when the voltage drops down to 70% ~ 35% of the rated voltage, the undervoltage release is to operate

with a time delay for discrimination purpose.
2.5.6.6 Where turbine-driven DC generating sets are arranged to operate in parallel, means are to be provided for the purpose of opening simultaneously all circuit-breakers of the generators when the overspeed tripping device of the driving turbine functions.
2.5.6.7 In the case of substantial reduction of speed of generators, the protective devices associated with generators are to remain effective.
2.5.6.8 Emergency generators are to be protected against short-circuit. Audible and visual alarm signals are to be given in the event of over-currents of emergency generators, which are not to lead to tripping of the circuit breakers of emergency generators.

2.5.7 Automatic load shedding

2.5.7.1 Proper load shedding or other equivalent arrangements are to be provided to automatically shed non-essential services, services for habitable conditions and where necessary, secondary essential services to ensure that the connected generator(s) is/are not overloaded. This load shedding may be carried out in one or more stages according to the overloading ability of the generator. In such case, the non-essential services are to be shed firstly.

2.5.8 Protection of power and lighting transformers

2.5.8.1 The primary windings of power and lighting transformers are to be protected against short-circuit and overload by multi-pole circuit-breakers or fuses. Overload protection may also be provided in the secondary windings.
2.5.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit breakers used for this purpose are to be capable of withstanding surge currents.

2.5.9 Protection of feeder circuits

2.5.9.1 Each feeder circuit is to be protected against overload and short circuits by a multi-pole circuit breaker arranged to interrupt simultaneously all insulated poles, or a multi-pole switch with fuses, but for a transitional emergency lighting feeder circuit it may also be accepted to use fuses only.
2.5.9.2 When a multi-pole switch with fuses is used, the following requirements are to be complied with:
(1) the fuse in the feeder sub-circuit from the main switchboard is to be fitted between the bus-bar and the switch;
(2) where the final sub-circuit from the distribution board has a rated current not exceeding 60 A and the consumers supplied by it can be disconnected at a nearby position, the switch may be omitted.
2.5.9.3 Circuits supplying consuming devices protected individually against overload (e.g. motors) may be provided with short-circuit protection only.
2.5.9.4 The protection of the steering gear circuits is to comply with 13.1.9.2 of PART THREE of the Rules.
2.5.9.5 Permanently fixed cables between the shore connection box and the main switchboard are to be protected by a circuit-breaker or an isolating switch and fuses. Such protection is to be fitted in the shore connection box.
2.5.9.6 In general, the interconnector feeder supplying the emergency switchboard from the main switchboard is to be protected at the main switchboard against overload and short-circuit. Where the system is arranged also for reverse power supply, the interconnector feeder is to be additionally protected at the emergency switchboard at least against short-circuit.

2.5.10 Protection of motors

2.5.10.1 Motors rated at 1.0 kW or above and all motors for essential services are to be protected individually against overload and short-circuit, and against undervoltage as required in 2.5.10.6 of this Section. The short-circuit protection can be provided by the same protective device for both the motor and its supply cable.
2.5.10.2 Protection of steering gear motors is to comply with 13.1.9.2 of PART THREE of the Rules.
2.5.10.3 The protective devices are to be designed to allow the flow of currents during the normal accelerating period of motors under normal conditions of service. When the time-current characteristics of the overload protective device of a motor are not adequate for the starting period of the motor, the overload protecting device may be rendered inoperative during the accelerating period provided that the protection against short-circuit remains operative and that the suppression of the overload protection is only temporary.
2.5.10.4 For continuous duty motors, protective devices are to have a time delay characteristic which

ensures reliable thermal protection of the motors for overload conditions. The maximum continuous current of the protective device is not to exceed 125% of the rated current of the protected motor.
2.5.10.5 For intermittent duty motors, the current setting and the delay characteristics for protective devices are to be chosen after considering the actual service condition.
2.5.10.6 Motors are to be provided with either:
(1) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted; or
(2) undervoltage release, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit, but so arranged that the motor restarts automatically and without excessive voltage drop or starting current on restoration of voltage.
The protective devices are to allow the motor to start when the voltage is above 85% of the rated voltage, and are without fail to intervene when the voltage is lower than approximately 20% of the rated voltage, at the rated frequency and with time delay when necessary.
2.5.10.7 When fuses are used to protect poly-phase motor circuits, consideration is to be given to protection against single phasing.

2.5.11 Protection of lighting circuits
2.5.11.1 Each lighting circuit is to be protected against overload and short-circuit.

2.5.12 Protection of storage batteries
2.5.12.1 Storage batteries, other than engine starting batteries, are to be protected against short-circuit with devices placed as near as practicable to the batteries.
2.5.12.2 Each battery charger is to be properly protected against discharging of the battery due to the reduction or loss of charging voltage.

2.5.13 Protection of meters, pilot lamps and control circuits
2.5.13.1 Voltmeters, voltage coils of measuring instruments, earthing indicators and pilot lamps together with their connecting leads are to be protected by fuses. A pilot lamp need not be individually protected provided the following conditions are satisfied:
(1) the pilot lamp is installed with the equipment in the same enclosure;
(2) the pilot lamp is supplied from the interior circuit of the enclosure of the equipment;
(3) the protection device in the circuit is rated less than 25 A;
(4) a fault in the pilot lamp would not jeopardize the supply to essential services.
2.5.13.2 The voltage coils of control and protective devices and equipment are to be protected by fuses. The coils themselves need not be protected provided the following conditions are satisfied:
(1) the coils are installed with the equipment in the same enclosure and protected by a general protective device;
(2) the coils are supplied from circuits of the equipment and the protective device of such circuits is rated less than 25 A.

2.5.14 Protection of semiconductor equipment
2.5.14.1 Semiconductor equipment is to be protected against overload and short circuit.

Section 6 AUXILIARY MACHINERIES

2.6.1 General requirements
2.6.1.1 Motors rated at 1.0 kW or above and motors required for essential services are to be supplied from distribution boards by separate final sub-circuits.
2.6.1.2 Every electric motor is to be provided with efficient means of starting and stopping which are, in general, placed near the motor, so as to be easily operated by the person controlling the motor.
2.6.1.3 Means are to be provided for the disconnection of the full load from all live poles of supply of every motor rated at 0.5 kW or above and its control gear. Where the control gear is mounted on or adjacent to a main or other distribution switchboard, a disconnecting switch in the switchboard may be used for this purpose. Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.
2.6.1.4 When the starter or any other apparatus for disconnecting the motor is remote from the motor, it is required that either:
(1) provision be made for locking the circuit disconnecting in the OFF position; or

(2) an additional disconnecting-switch be fitted near the motor; or
(3) the fuse in each live pole or phase be so arranged that it can be readily removed and retained by an authorized person.
2.6.1.5 Where a single master-starter system (i.e. a starter used for controlling a number of motors successively) is used, undervoltage and over-current protection, means of isolation and a running indicator are to be provided for each motor, not less effective than those required for systems using a separate starter for each motor. Where the starter system is of an automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services, the starting portion is to be duplicated, and means are to be provided for change-over in the event of failure of one of the starters.
2.6.1.6 All motors with field adjustment for speed control are to be provided with a device which renders the motors to be started only when the field is fully excited.
2.6.1.7 The undervoltage, overload and short-circuit protection for motors are to comply with the requirements of Section 5, Chapter 2 of this PART.

2.6.2 Steering gear
2.6.2.1 Electrical or electrohydraulic steering gears are to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.

2.6.3 Permanently installed submersible bilge pumps
2.6.3.1 The motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard. The feeder cables are to be installed in continuous lengths from above the bulkhead to the motor terminals.
The cables are to be impervious-sheathed and armoured. Cables and their connections to such pumps are to be capable of operating under a head of water equal to the height of the bulkhead deck.
2.6.3.2 Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck. If an additional start-stop push button is provided near the motor, the circuits are to be so arranged as to ensure that all control circuits of the start-stop push button may be disconnected from the position above the bulkhead deck.
2.6.3.3 The power source of a permanently installed submersible bilge pump is also to comply with the relevant requirements of Section 5, Chapter 3, PART THREE of the Rules.

2.6.4 Deck machinery
2.6.4.1 Electromagnetic brakes for electrical deck machinery are to have, in addition, a hand release device.
2.6.4.2 If not otherwise specially required in their specifications, the duty of windlass motors and winch motors is to be rated for not less than 30 min.
2.6.4.3 Boat winch motors are to be provided with limit switches for cutting off the power supply upon returning of the boat to its original position.
2.6.4.4 The control device of boat winch motors is to be interlocked with the manual drive and manual brake.

2.6.5 Fire safety equipment
2.6.5.1 The electrical power supply to fire pump motors and fixed emergency fire pump motors is to comply with the relevant requirements of this PART.
2.6.5.2 The electrical power supply to automatic sprinkler systems and water-spraying systems is to comply with the relevant requirements of the International Code for Fire Safety Systems.

2.6.6 Stopping of ventilating fans and oil pumps
2.6.6.1 Power ventilation of accommodation spaces, service spaces, cargo spaces and control stations is to be capable of being stopped from an easily accessible position outside the space being served. This position is not to be readily cut off in the event of a fire in the space served.
The exhaust fans in the exhaust ducts from galley ranges are to be capable of being shut off within the galley.
2.6.6.2 Stopping of the ventilation fans and oil pumps in machinery spaces
(1) The means provided for stopping the power ventilation serving the machinery spaces are to be grouped so as to be operable from two positions outside the space served, one of which is to be easily accessible and close to such space, and is not to be readily cut off in the event of a fire in the space served.
The means provided for stopping the power ventilation of the machinery spaces are to be entirely separate

from the means provided for stopping ventilation of other spaces.
(2) Means of control are to be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). Except oil separators, such means of control are to be situated outside each related space so that it will not to be cut off in the event of a fire in the space served.
2.6.6.3 Additional requirements for passenger ships
(1) In passenger ships, the controls required in 2.6.6.2 of this Section are to be situated at one control position or grouped in as few positions as possible. Such positions are to have safe access from the open deck.
(2) In passenger ships carrying more than 36 passengers, power ventilation, except machinery space and cargo space ventilation and unless otherwise specified in PART SIX of the Rules, is to be fitted with controls so grouped that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.
Fans serving power ventilation systems to cargo spaces are to be capable of being stopped from a safe position outside such spaces.

2.6.7 Integrated cargo and ballast systems on tankers

2.6.7.1 The following requirements are applicable to integrated cargo and ballast systems on tankers.
2.6.7.2 An integrated cargo and ballast system means any integrated hydraulic and/or electric system used to simultaneously drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).
2.6.7.3 The operation of the cargo and/or ballast systems may be necessary, in certain emergencies or during navigation, to enhance the safety of the tanker, and measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system (including its control and safety systems).
2.6.7.4 The following design features are, inter alia, to be fitted:
(1) the emergency stop circuits of the cargo and ballast systems are to be independent from the circuits of the control systems. A single failure in the control system circuits or the emergency stop circuits is not to render the integrated cargo and ballast system inoperative;
(2) manual emergency stops of the cargo pumps are to be arranged in a way that they will not cause the stop of the power pack, rendering ballast pumps inoperable;
(3) the control systems are to be provided with backup power supply, which may be achieved by duplicated power supply from the main switch board. The failure of any power supply is to activate an audible and visual alarm at each location where the control panel is fitted;
(4) in the event of failure of an automatic or remote control system, a secondary means of control is to be available for the operation of the integrated cargo and ballast system. This may be achieved by manual overriding and/or redundancy control arrangements within the control system.

2.6.8 Vehicle ramp control system for ferries

2.6.8.1 The vehicle ramp control station is to be so arranged that the movement of the ramp can be observed by the operator.
2.6.8.2 An audible and visual alarm is to be given for power failure of the control system. At the same time, the ramp is to be kept at its position automatically. When the power supply is recovered, operation of the control mechanism is not to be continued until it its reset.
2.6.8.3 The indicator of ramp conditions is to be provided in the control station.
2.6.8.4 Devices for preventing control and driving circuits from action are to be provided under the following conditions:
(1) any of the covers is not taken off;
(2) enclosures of vehicles are not closed.
2.6.8.5 Audible and visual indications are to be given continuously at a conspicuous position by the ramp when the ramp is running.
2.6.8.6 Where the ramp is fixed by a retractable locking device, means are to be provided to ensure that the power will not be interrupted when the locking device is clutched and that no launching of the ramp is possible before the locking device is disengaged.
2.6.8.7 Where a ramp, in addition to that for the stern door, is provided for access from the wharf, its angle to the horizontal is to be less than 10° before the stern door is opened or closed.
2.6.8.8 The maximum inclination of the access ramp in operation to the horizontal is not to be more than the predetermined angle. An audible and visual alarm is to be given if the inclination exceeds the allowable angle.

2.6.8.9 Where a remote locking device is fitted, alternative means is to be provided for locking the ramp in case of failure of the locking control or locking mechanism.

Section 7 LIGHTING AND NAVIGATION LIGHTS

2.7.1 General requirements

2.7.1.1 The lighting fittings fitted in cargo holds, exterior passageways, or other spaces where they are liable to mechanical damage, are to be provided with robust protective grids.

The lighting fittings located in such spaces where they are liable to considerable vibration are to be provided with means for damping the vibration.

Where lighting fittings are directly fixed on wooden panelling or other inflammable materials, precautions are to be taken against overheating and fire.

2.7.1.2 The switches of lighting fittings for baggage rooms, mail rooms, provisions rooms, refrigerated spaces and other similar spaces are not to be fitted inside such spaces, and are to be provided with a pilot lamp. Switches for lighting used in wet spaces and in spaces where the risk of explosion might arise are to be capable of isolating all insulated poles.

2.7.1.3 The warning signs showing "DANGER! HIGH VOLTAGE!" are to be provided in the spaces adjacent to discharge lamps operating at a voltage over 250 V and elsewhere as necessary.

2.7.2 Supply and control

2.7.2.1 The lighting point supplied by each final sub-circuit of rating of more than 16 A at the lighting distribution board is not to exceed one. The number of lighting points supplied by each final sub-circuit of rating 16 A or less at the lighting distribution board is not to exceed:

10 for circuits of rating 55 V or less;

14 for circuits of rating 56 ~ 120 V circuits;

24 for circuits of rating 121 ~ 250 V circuits.

In final sub-circuits for cornice lighting, panel lighting and electrical signs where lampholders are closely grouped, the number of points supplied is unrestricted provided that maximum operating current in the sub-circuit does not exceed 10 A.

Final sub-circuits for lighting are not to supply heating and power appliances, except for small galley equipment (e.g. toasters, mixers, coffee makers), small motors (e.g. of desk and cabin fans, refrigerators), wardrobe heaters and similar items.

2.7.2.2 The lighting for main engine rooms, large machinery spaces other than main engine rooms, large galleys, passageways (including accesses), stairways leading to boat decks, public spaces and berthing compartments accommodating more than 16 passengers is to be supplied by at least two final sub-circuits, and one of which may be the final sub-circuit for emergency lighting so that in the event of failure of any one of the sub-circuits the other one could still maintain the necessary lighting for such spaces. The lighting points for main engine and boiler rooms are to be distributed alternately.

In machinery spaces, the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are to be adequately illuminated so that defects and leakage will readily be observed. In machinery spaces of category A and whenever practicable in other machinery spaces, the arrangements for storage, distribution and utilization of oil used in pressure lubrication systems are also to be adequately illuminated.

2.7.2.3 Each main vertical fire zone is to be provided with at least two separate lighting feeders, one of which may be an emergency light feeder.

2.7.2.4 The permanently fixed lighting in cargo holds is to be controlled by switches located in a suitable position outside the cargo holds, capable of isolating all insulated poles and provided with a pilot lamp to indicate the power supply.

2.7.2.5 The degree of protection of lighting fittings located in various spaces in ships is to comply with the requirements of Table 1.3.2.2 of this PART. Lighting switches for spaces with special requirements are to be installed in accordance with the requirements of 2.7.1.2 of this Section.

2.7.2.6 Lighting circuits are to be provided with protection in accordance with the requirements of 2.5.11.1 of this Chapter.

2.7.2.7 A main electrical lighting system is to provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew, and is to be supplied from the main source of electrical power.

2.7.2.8 In assessing the current rating of lighting circuits, in case of lack of accurate information, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W. 200VA are to be counted for

each lighting socket in accommodation spaces.

2.7.3 Emergency lighting

2.7.3.1 The arrangement of emergency lighting and the supplementary emergency lighting for ro-ro passenger ships are to comply with the relevant requirements of Section 2 of this Chapter.

2.7.3.2 In passenger ships, the means of escape, including stairways and exits, are to be marked by lighting or photo-luminescent strip indicators complying with acceptable standards① and placed not more than 0.3 m above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits.

If electric illumination is used, it is to be supplied by the emergency source of power (see 2.2.2.1(1)③ of this Chapter).

2.7.3.3 All emergency lighting fittings are to be provided with a prominent mark or structurally different from other luminaries.

2.7.3.4 No local switch is to be installed in the transitional emergency lighting feeders.

2.7.3.5 No local switch is to be installed in the emergency lighting circuits in the spaces so specified in 2.2.2.1(1) and 2.2.3.1(2) of this Chapter except for the emergency lights in the navigation bridge, at the stowage positions of lifeboats and life rafts.

2.7.3.6 Respective power sources of main and emergency switchboards, associated transforming equipment (if any), the main or emergency switchboard and lighting switchboard (excluding section board and distribution board) are not to be provided in the same space so that the two systems would not fail simultaneously in the event of a fire or other casualty in any space containing these appliances.

2.7.3.7 In passenger ships, supplementary lighting shall be provided in all cabins to clearly indicate the exit so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, shall automatically illuminate when power to the normal cabin lighting is lost and remain on for a minimum of 30 min.

2.7.4 Navigation lights

2.7.4.1 Each navigation light is to be supplied by a sub-circuit connected separately to the control box fitted at an easily accessible position on the navigation bridge and is to be controlled and protected in each insulated pole by a switch and a fuse or by a circuit breaker fitted in the control box.

2.7.4.2 The control box for navigation lights is to be supplied directly from the main switchboard and emergency switchboard. Where the transitional source of emergency power is provided according to Section 2 of this Chapter, the control box is to be supplied directly from the emergency switchboard and transitional emergency charging and discharging switchboard.

2.7.4.3 The change-over switch for the supply circuits required in 2.7.4.2 of this Section is to be installed on the control box or at a suitable position on the navigation bridge.

2.7.4.4 Each navigation light is to be provided with an automatic indicator giving an audible and visual indication of failure of the light. If a visual signal is used and connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal, and the audible and visual alarms for failure of the power source of the control box are to be provided.

2.7.4.5 The power supply from the control box of navigation lights may be extended to the signal lights required in the International Regulations for Preventing Collisions at Sea, and other consumers are not to be connected to the box.

Section 8 INTERNAL COMMUNICATION SYSTEMS

2.8.1 Main engine telegraph system

2.8.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propeller (hereinafter referred to as the normal control position of the propeller) are normally controlled. One of the means is to be the main engine telegraph system complying with the requirements of 2.8.1.2 of this Section.

2.8.1.2 The main engine telegraph system is to be in compliance with the following requirements:

(1) The controls of the transmitters and receivers are to be safeguarded by suitable means against being

---

① Refer to the Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships adopted by IMO resolution A.752(18).

inadvertently moved.
(2) The engine telegraph is to be a two-way system in which the signal given by the receiver is also immediately discernible at the transmitter.
(3) In the case of installations with several control positions the acknowledged command must be indicated at all control positions. Where a control position is selected by switching, an additional indication is to be provided to show which one is in use.
(4) Both the transmitter and the receiver are to be equipped with a call-up device which remains in operation from the start of the command transmission till it is correctly acknowledged. The audible signal is to be audible at any position in the engine room. If necessary, a visual signal is to be provided in addition to the audible signal.
(5) An audible alarm is to be provided for wrong direction of rotation of the main engine (applicable to reversible main engines) in the normal control position of the propeller.
(6) Power is to be supplied by the independent final sub-circuit and audible and visual alarms are to be provided on the navigation bridge for the purpose of indicating the failure of power supply.
2.8.1.3 The other means for communicating orders required in 2.8.1.1 may be an emergency engine telegraph system, the functions of which are to be in compliance with the requirements of 2.8.1.2(1) and (2), and which is to be supplied by the emergency power source.
2.8.1.4 A telephone system required in 2.8.2.2(4) may be fitted instead of the emergency engine telephone system.

2.8.2 Important telephone systems
2.8.2.1 The important telephone systems are to be such as to ensure clear vocal intercommunication in all conditions of the ship.
2.8.2.2 The telephone system is to be provided in the following spaces:
(1) Bridge – Engine control room;
(2) Bridge – Steering gear control position in steering gear compartment;
(3) Bridge – Radio room, not required if communication can be made without telephone;
(4) Bridge – Normal control position of the propeller, not required if an emergency main engine telegraph system is provided;
(5) Bridge – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions;
(6) Engine control room – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions.
2.8.2.3 The telephone systems required in 2.8.2.2 are to be individual links, although a common telephone system may be used if it is ensured that the bridge can cut into existing conversations at all times.
2.8.2.4 The common telephone system described in 2.8.2.3 is to be an independent one and is allowed to provide voice communications, in addition to the spaces described in 2.8.2.2, only for those that are relevant to ship safety, such as the fire control station, CO_2 room and emergency generator room, etc.
2.8.2.5 Two-way calling equipment is to be provided for the telephone systems fitted in the engine room (except engine control room) and designed as being audible at any position in the engine room under full-power operation of the main propelling plant, and visual signals are to be provided in addition to the audible signals.
2.8.2.6 The important telephone system is to remain operable in case of failure of the main power supply.

2.8.3 Communication in an emergency
2.8.3.1 An intercommunication system is to be provided which enables commands to be transmitted between strategic positions, i.e. the emergency control station, the muster and embarkation station of survival craft and navigation bridge etc.
2.8.3.2 The communication system may comprise portable or permanently installed equipment, and is to remain operable in case of failure of the main power supply.

2.8.4 Engineers' alarms
2.8.4.1 An engineers' alarm is to be provided to be operated from the engine room or engine control room and is to be clearly audible in the engineers' accommodation.
2.8.4.2 The audible alarm may be mounted centrally in the passageway of the engineers' accommodation, or individually in the cabins and the mess.
Where a decentralized arrangement is used, it is to be possible to transmit the alarm to the engineers both individually and collectively.

Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD

2.9.1 General emergency alarms

2.9.1.1 In order to sound general emergency signals, a general emergency alarm system comprised of the ship's whistle or siren and additionally an electrically operated bell or klaxon or other equivalent apparatus, is to be provided on all passenger ships and cargo ships of 500 gross tonnage and above. In passenger ships, the alarm is to be capable of being given separately or simultaneously to crew and passengers. Cargo ships of 500 gross tonnage and above may not be fitted with an independent general emergency alarm system when a public address system meeting the requirements of 2.9.2.1 (1) to (8) has already been provided.

2.9.1.2 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle or siren, also from at least one other strategic points[①]. The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message from the public address system. For passenger ships there is also to be an additional activation point in the safety centre.

2.9.1.3 Where the general emergency alarm system is in operation, the acoustic system for entertainment is to be interrupted automatically.

2.9.1.4 The general alarm system is to be supplied from special feeders, being capable of automatically converting to the emergency source of electrical power in the event of failure of the main source of electrical power. In passenger ships, the system is also to be capable of being supplied by a temporary emergency source of electrical power.

2.9.1.5 The system is to be audible throughout all the accommodation and normal crew working spaces, including open decks in passenger ships.

The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB(A) and at least 10 dB(A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather. The sound pressure levels at the sleeping position in cabins and in cabin bathrooms are to be at least 75 dB(A) and at least 10 dB(A) above ambient noise levels.

2.9.1.6 Each electrically operated bell or klaxon or other equivalent warning system is to be separately protected against short circuit.

2.9.2 Public address system

2.9.2.1 Cargo ships of 500 gross tonnage and above are to be provided with a public address system in compliance with the following requirements:

(1) capable of broadcasting messages from the navigation bridge and fire control station etc. to all spaces where crew are normally present and muster stations;

(2) no operation required of receivers to accept the broadcast message;

(3) protected against unauthorized use;

(4) amplifiers have sufficient output power so that all loudspeakers for the purpose of emergency announcement can be operated at the same time;

(5) arranged to prevent feedback or any other interference;

(6) with the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

① in interior spaces 75 dB(A) and at least 20 dB(A) above the speech interference level;

② in exterior spaces 80 dB(A) and at least 15 dB(A) above the speech interference level;

(7) capable of being supplied by both main and emergency power sources;

(8) if the public address system is used to give the general alarm, the following requirements are to be fulfilled:

① the performance requirements of 2.9.1 of this Section are to be complied with;

② at least two amplifiers are to be provided, each of them separately supplied;

③ the loudspeaker circuits are to be so arranged that an announcement at a reduced acoustic irradiation is maintained in the event of a failure of an amplifier or loudspeaker circuit;

④ where loudspeakers with built-in volume controls are used, the volume controls are to be disabled by the release of the alarm signal;

⑤ it is to be possible to transmit the clearly audible alarm signal at all times and other simultaneous signal transmissions are to be automatically interrupted;

---

① Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

⑥ an independent short-circuit protection is to be provided for each loudspeaker.

2.9.2.2 All passenger ships are to be provided with a public address system in compliance with the following requirements:

(1) capable of simultaneously broadcasting messages from bridge and central control station, etc. to all spaces where crew and passengers or both are normally present and muster stations, and capable of broadcasting messages to crew and passengers separately;

(2) complying with the requirements of 2.9.2.1(2) to (6);

(3) capable of interrupting at the control position on the navigation bridge any broadcast of the system from any other position onboard;

(4) the spaces where control units of the system are located are the control stations as defined in Chapter II-2 of the SOLAS Convention, and each of the control stations is to be provided with the following emergency function controls:

① clearly indicating any emergency function;

② automatically overriding any other input system or programme;

③ automatically overriding all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces;

(5) at least two independent and separate amplifiers are to be provided, each of them separately supplied;

(6) at least two loudspeaker circuits connected to their respective amplifiers are to be installed in each fire zone, and their cables are to be laid as widely apart as practicable for their entire length;

(7) independent short-circuit protection is to be provided for each loudspeaker;

(8) capable of being supplied by main, emergency and temporary emergency sources of electrical power;

(9) if the public address system is used to give the general emergency alarm, the requirements of 2.9.1 of this Section are also to be complied with.

2.9.3 Pre-discharge alarms of fire extinguishing medium

2.9.3.1 In any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches (except general cargo holds), and other spaces in which personnel normally work or to which they have access, which are protected by fixed gas fire-extinguishing systems, means are to be provided for automatically activating audible and visual alarms for the release of fire-extinguishing medium. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.2 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces which are protected by fixed high-expansion foam fire-extinguishing systems are to be provided with audible and visual alarms for the release of fire-extinguishing medium in order to give warning of the release of the system. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.3 The above-mentioned alarm system is to be supplied by the emergency source of electrical power.

2.9.3.4 The fixed fire-extinguishing system for the protection of machinery spaces where main propulsion engine and main generator set are located is to be designed such that any action other than the release of fire extinguishing media are not to lead to automatic shutdown of ventilation fans and oil pumps in these machinery spaces,such as opening the release box (cabinet) door during fire drills.

2.9.4 Elevator alarms

2.9.4.1 Elevators having an internal control are to be fitted with an emergency audible call-up device capable of being operated in the car and the alarm signal is to be transmitted to the positions where persons are normally present.

2.9.4.2 The emergency audible call-up device is to be independent from the power and control circuits of the elevator and supplied by the emergency source of electrical power.

2.9.5 Alarms for closing refrigerated spaces

2.9.5.1 Where the doors to refrigerated spaces such as refrigerated holds and refrigerating food chambers cannot be opened from the inside, an alarm capable of being activated within the spaces upon inadvertent closing of such doors is to be fitted and the alarm transmitted to normally manned positions.

2.9.6 Fire detection and fire alarm systems

2.9.6.1 The fire detection and fire alarm systems are to comply with the relevant requirements of Chapter II-2 of the SOLAS Convention in force and Chapter 9 of the International Code for Fire Safety Systems.

2.9.6.2 There are to be not less than two sources of power supply for the fixed fire detection and fire alarm system, one of which is to be an emergency source. The supply is to be provided by separate feeders

reserved solely for that purpose. Such feeders are to run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

2.9.6.3 Operation of the automatic changeover switch or a failure of one of the power supplies is not to result in permanent or temporary degradation of the fixed fire detection and fire alarm system.

2.9.6.4 Where the fixed fire detection and fire alarm system would be degraded by the momentary loss of power, a source of stored energy having adequate capacity is to be provided to ensure the continuous operation during changeover between power supplies.

2.9.6.5 Connection of electrical power supplies to an automatic changeover switch is to be arranged such that a fault will not result in the loss of all supplies to the automatic changeover switch.

2.9.6.6 The fixed fire detection and fire alarm system emergency power may be supplied by an accumulator battery. Where the system is supplied from an accumulator battery, the arrangements are to comply with the following requirements:

(1) The accumulator battery is to have the capacity to operate the fire detection system under normal and alarm conditions during the period required by 2.2.2 or 2.2.3 of this Chapter for the emergency source of power supply.

(2) The rating of the charge unit, on restoration of the input power, is to be sufficient to recharge the batteries while maintaining the output supply to the fire detection system.

(3) The accumulator batteries are to be suitably located for use in an emergency.

(4) The feeders are to run from the accumulator battery or the accumulator battery charging and discharging board to the automatic changeover switch without passing through any other distributor.

2.9.7 Fire doors

2.9.7.1 The power, control, indication and alarm systems of fire doors as required in Chapter II-2 of the SOLAS Convention in force are to be supplied by the emergency source of electrical power.

2.9.7.2 For passenger ships, an indicator to show whether each door operated by remote control is opened or closed is to be provided in the normally manned control station.

2.9.7.3 For passenger ships, the control and indication systems for the fire doors are to be designed on the fail-safe principle, provided with a release system having manual reset capable of being operated from either side of the door.

2.9.8 Watertight doors in passenger ships

2.9.8.1 The power circuit and its associated control, indication and alarm circuits for power-operated sliding watertight doors are to be supplied either directly by the emergency switchboard or by a dedicated distribution board connected with the emergency switchboard above the bulkhead deck.

2.9.8.2 Where a motor is provided for the opening and closing of the watertight doors, unless an independent reserve energy is provided, the power source is to be capable of being automatically changed over to the transitional source of emergency electrical power in the event of failure of either the main or the emergency source of electrical power. The capacity of the motor is to be sufficient to operate the watertight door at least three times, i.e. closed – open – closed.

2.9.8.3 A single electrical failure in the operating or control system of a power-operated sliding watertight door is not result in a closed door opening or interrupt any manual operation of the watertight door.

2.9.8.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit as near as practicable to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console on the navigation bridge.

2.9.8.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a watertight door are not result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

2.9.8.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water as follows:

(1) electric motors, associated circuits and control components: IPX7;

(2) door position indicators and associated circuit components: IPX8.

Where the water pressure testing is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 h;

(3) door movement warning signals: IPX6.

2.9.8.7 Electrical controls of watertight doors, including their cables, are to be kept as close as practicable

to the bulkhead in which the doors are fitted and so arranged as to minimize the likelihood of them being involved in any damage which the ship may sustain.

2.9.8.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least 5 s but not more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In passenger areas and areas where ambient noise level exceeds 85 dB(A), the audible alarm is to be supplemented by an intermittent visual signal.

2.9.8.9 The central operating console is to be fitted on the navigation bridge, having a "master mode" switch with the following two modes of control:

(1) "Local control" mode for normal use, which is to allow any door to be locally opened and locally closed after use without automatic closure; and

(2) "Door closed" mode for emergency use, which is to automatically close any door that is opened while still permitting any door to be opened locally but with automatic reclosure upon release of the local control mechanism.

2.9.8.10 The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door. Visual indicators showing whether the doors are open or closed are to be provided both on the central operating console and at hand operation positions above the bulkhead deck for watertight doors. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely, a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

2.9.8.11 It is not to be possible to remotely open any watertight door from the central operating console.

2.9.9 Watertight access doors and hatch covers, etc. in cargo ships

2.9.9.1 For sliding watertight doors provided to ensure the watertight integrity of internal openings which are used while at sea, their operation, control and indicators are to comply with the following requirements:

(1) capable of being closed remotely at the navigation bridge and operated at either side of the bulkhead;

(2) an indicator to show whether the door is open or closed is to be provided in the control position;

(3) audible and visual alarms are to be given as the door is closed;

(4) each power-operated door is to be provided with an individual hand-operated mechanism, and it is to be possible to open and close the door by hand from each side.

2.9.9.2 Access doors and hatch covers normally closed at sea to ensure the watertight integrity of internal openings are to be provided with means of indication showing locally and on the navigation bridge whether these doors or hatch covers are open or closed.

2.9.9.3 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, except for cargo hatch covers, are to be fitted with indicators on the navigation bridge to show whether the openings are open or closed.

2.9.9.4 The electrical power, control, indication and audible and visual alarms required in 2.9.9.1 are to remain operable in the event of the failure of the main source of electrical power.

2.9.10 Boundary doors of special category spaces and ro-ro spaces

2.9.10.1 The requirements below are applicable to boundary doors of special category spaces or ro-ro spaces as defined in Chapter 9, PART TWO of the Rules. These spaces may be flooded through the doors. In cargo ships, where no part of a side shell door or stern door is under the highest waterline and the open area of the door is not greater than 6 m^2, the requirements from 2.9.10.2 to 2.9.10.5 of this Section are not applicable.

2.9.10.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator lights.

2.9.10.3 The indicator system is to be designed① on the fail-safe principle and is to show by a visual

---

① The indicator system is considered designed on the fail-safe principal when the following are provided:

a. The indication panel is provided with:
   – a power failure alarm;
   – an earth failure alarm;
   – a lamp test;
   – separate indication for door closed, door locked, door not closed and door not locked.

b. Limit switch electrically closed when the door is closed (when more limit switches are provided, they may be connected in series).

c. Limit switch electrically closed when securing arrangements are in place (when more limit switches are provided,

alarm if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of electrical power or other secure power supply (e.g. UPS).
The sensors of the indicator system are to be protected from water, icing and mechanical damage.
2.9.10.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbor/sea voyage", so arranged that an audible alarm is given on the navigation bridge if the vessel leaves harbor with the bow door or inner door not closed or with any of the securing devices not in the correct position.
2.9.10.5 For side shell doors or stern doors, a water leakage detection system① with audible alarm and television surveillance is to be arranged on passenger ships to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. A water leakage detection system② with audible alarm is to be arranged on cargo ships to provide an indication to the navigation bridge.
2.9.10.6 For inner doors, a water leakage detection system① with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the doors.
2.9.10.7 Between the bow door and the inner door a television surveillance system① is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.
2.9.10.8 A drainage system① is to be arranged in the area between the bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system② is to be equipped with an audible alarm on the navigation bridge being set off when the water levels in these areas exceed 0.5 m or the high water level alarm threshold, whichever is lesser.
2.9.10.9 For ro-ro passenger ships, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means (e.g. television surveillance) so that any movement of vehicles in adverse weather conditions, or unauthorized access by passengers thereto, will be detected whilst the ship is underway.

2.9.11 Emergency dumping system of dredgers and barges

2.9.11.1 For dredgers and hopper barges of which the operation draft is marked according to Section 13, Chapter 1, PART TWO of the Rules, emergency devices, controlled from the navigating bridge, are to be fitted so that the discharge of spoil is possible in case of failure of the main electric power supply or the main hydraulic unit and/or a single failure of the normal control systems.

Section 10 HEATING AND COOKING EQUIPMENT

2.10.1 General requirements

2.10.1.1 All electric space heaters are to be installed permanently.
2.10.1.2 Heating appliances are not to be installed in positions where combustible gases and dusts are likely to accumulate.
2.10.1.3 Heating appliances are to be so mounted that there will be no risk of excessive heating of adjacent decks, bulkheads or other surroundings.

2.10.2 Control and installation of heating and cooking equipment

2.10.2.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters, a single-pole switch will be acceptable.

2.10.3 Supply of heating equipment

2.10.3.1 Each heater is to be connected to a separate final sub-circuit for heating except that up to ten

---

they may be connected in series).

d. Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked.
e. In the case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place, as appropriate.

① The system is to be designed on the fail-safe principle, see footnote of 2.9.10.3 of this Section.

small heaters of total connected current rating not exceeding 16 A may be connected to a single final sub-circuit for heating.

Section 11 STORAGE BATTERIES

2.11.1 Arrangement and installation

2.11.1.1 Storage batteries are not to be installed in spaces where they are exposed to excessively high or low temperatures, water splattering, steam or other factors which will impair their serviceability or shorten their service life. They are to be installed in such a way that persons will not be endangered and equipment will not be damaged by escaping gases or electrolytic leakage.

2.11.1.2 Storage batteries are to be so installed as to ensure accessibility for replacing cells, inspection, testing, topping-up and cleaning.

2.11.1.3 Storage batteries are not to be installed in the accommodation area. An exception may be granted for gastight cells, where charging does not result in the development of harmful gases.

2.11.1.4 Suitable protection measures are to be provided where the storage batteries are exposed to the risk of mechanical damage or falling objects.

2.11.1.5 Storage batteries connected to a charging device with a power output① of more than 2 kW are to be housed in a room assigned to the batteries only, or in a box or a locker on open deck.

2.11.1.6 Storage batteries connected to a charging device with a power output of 0.2 kW to 2 kW are to be installed in accordance with 2.11.1.5. They also may be installed in a box or a locker within a suitable space, or may be installed in an open position in a well ventilated machinery space.

2.11.1.7 Storage batteries connected to a charging device with a power output of less than 0.2 kW may be installed in an open position or in a battery box in any suitable space.

2.11.1.8 A gap of more than 20 mm is to be provided around each battery, and non-hygroscopic and electrolyte-resistant insulating material is to be used for the separation, dunnage and fixing of the battery. Measures are to be taken to prevent any leaking electrolyte from entering in contact with the ship's structure.

2.11.1.9 Any surface of dedicated battery rooms, boxes, lockers and associated ventilation ducts, etc., liable to corrosion, by the electrolyte or by the gas escaped from the electrolyte, are to be protected against corrosion.

2.11.1.10 Prime mover starter batteries are to be installed as close as practicable to the primer mover served.

2.11.1.11 Storage batteries used as emergency and temporary emergency source of electrical power are to be installed in accordance with the requirements of 2.2.1.2 of this PART.

2.11.1.12 A warning notice of "NO SMOKING OR NAKED LIGHTS" is to be displayed adjacent to doors of battery rooms and covers of battery boxes or lockers.

2.11.2 Ventilation

2.11.2.1 Battery rooms, boxes and lockers are to be ventilated to prevent the accumulation of flammable gases.

2.11.2.2 Natural ventilation may be employed if the required number of air changes is small and the duct can be run directly from the top of the battery room, box or locker to the open air above, with no part of the duct more than 45° from the vertical.

2.11.2.3 For natural ventilation of the battery room, the cross-sectional area A of the inlet is to be equal to that of the outlet, not less than:

(1) for vented type batteries

$$A = \frac{50 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

(2) for valve-regulated sealed batteries

$$A = \frac{20 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

where: U_n — nominal voltage of the battery, in V;

Q — battery capacity, in Ah;

n — number of cells in series.

2.11.2.4 Mechanical ventilation is to be provided for the battery room, box or locker containing vented

---

① Power output of the charging device is to be calculated from the maximum charging current multiplied by the rated voltage of batteries.

type batteries with a total charging power higher than 2 kW.

2.11.2.5 Except those boxes and lockers on open deck or within the spaces required in 2.11.1.6 and 2.11.1.7 of this Section, the ventilation system for battery rooms, boxes or lockers is to be separate from other ventilating systems. The exhaust ducting is to be led to a location where any flammable gas can be safely diluted, away from any source of ignition, and the inlet ducting is to be led into spaces where flammable gases may accumulate. The outlet is to be situated at the top and the inlet at the bottom with the means to prevent the ingress of water and flame.

2.11.2.6 Mechanical ventilators for battery rooms, boxes or lockers are to be provided with means to prevent sparking in case of the impeller touching the casing. Non-metal impellers are to be of an antistatic material.

2.11.2.7 All openings of battery rooms, other than ventilation openings, are to be effectively sealed to prevent the explosive gas from entering adjacent compartments.

2.11.2.8 The quantity Q of air expelled from the rooms, boxes or lockers containing vented type batteries is not to be less than:

$$Q = 0.11\ In \quad m^3/h$$

where: I — the maximum charging current during the development of gas, but not less than 25% of the maximum charging current output by the charging device, in A;

n — number of battery cells.

2.11.2.9 The quantity of air expelled from the rooms, boxes or lockers containing valve-regulated sealed batteries may be reduced to 25% of that required in 2.11.2.8.

2.11.3 Charging facilities

2.11.3.1 Charging facilities are to be provided for all storage batteries such that the completely discharged battery can be recharged to the rated capacity in not more than 10 h, having regard to the service requirements.

2.11.3.2 Suitable means are to be provided for controlling and monitoring charging of storage batteries, and to protect them in accordance with the requirements of 2.5.12.2 of this PART.

2.11.3.3 For floating circuits or any other conditions where the load is connected to the storage battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

2.11.4 Electrical equipment

2.11.4.1 The installation of electrical equipment is to be avoided in battery rooms. Where this is necessary, the explosion-proof electrical equipment required in 1.3.3.3 of this PART is to be selected.

2.11.5 Recording of the type, location and maintenance cycle of batteries

2.11.5.1 A schedule of batteries used for essential and emergency services is to be compiled and maintained. The schedule, which is to be reviewed by the ISC attending Surveyor, is to include at least the following information regarding the batteries:

— type and manufacturer's type designation;
— voltage and ampere-hour rating;
— location;
— equipment and/or system(s) served;
— maintenance/replacement cycle dates;
— date(s) of last maintenance and/or replacement;
— for replacement batteries in storage, the date of manufacture and shelf life.

2.11.5.2 Procedures are to be put in place to ensure that, where batteries are replaced, they are of an equivalent performance type.

2.11.5.3 Where valve-regulated sealed batteries are replaced by vented type batteries, it is to be ensured that there is adequate ventilation as so required in 2.11.2.4 and 2.11.2.8 of this Section, and that the requirements in 2.11.1 of this Section relevant to the location and installation of vented type batteries are complied with.

2.11.5.4 Details of the schedule reviewed by the Surveyor and of the procedures, as mentioned above, are to be included in the ship's safety management system. Details of the schedule and of the procedures are to be integrated into the ship's operational maintenance routine as appropriate and be inspected at appropriate intervals, and to be verified by the surveyor.

Section 12 CABLES

2.12.1 General requirements

2.12.1.1 Cables are to be selected according to the environmental conditions of the space where the cables will be installed, methods of installation, rated current, duty, diversity factor, etc.

2.12.1.2 The rated voltage of any cable is not to be lower than the nominal voltage of the circuit for which it is used.

2.12.1.3 Portable electrical equipment is to be provided with movable flexible cables.

2.12.1.4 Cables used in the non-earthing system are to be provided with suitable rating so as to sustain the additional stress of the cable insulation in the event of failure.

2.12.2 Choice of insulating material and voltage rating

2.12.2.1 The rated maximum operating temperature of the insulating material is to be at least 10℃ higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.12.2.2 The insulating material of cables is generally to be selected in accordance with Table 2.12.2.2. The selection of other insulating materials is to comply with IEC publication 60092.

Maximum Rated Conductor Temperature of Insulating Material Table 2.12.2.2

Insulating material	Abbrev.	Max. rated conductor temp. (℃)	
		Normal operation	Short circuit
Ethylene propylene rubber	EPR	90	250
High modulus or hard grade ethylene propylene rubber	HEPR	90	250
Cross-linked polyethylene	XLPE	90	250
Silicone rubber	S95	95②	350①
Cross-linked polyolefin material for halogen-free cables	HF90	90	250

Notes: ① Applicable only to power cables and not appropriate for tinned copper conductors.

② The maximum rated conductor temperature for silicone rubber is 180℃, but the practical maximum working temperature is limited by the sheathing materials.

2.12.2.3 The rated voltage of a cable is expressed in U_0/U, where U_0 is the rated power voltage between conductor and "earth" (or metallic screen or surrounding medium of cables) and U is the rated power voltage between conductors. The choice of rated voltage of the cables depends on the system voltage and the system earthing arrangements, which is not to be lower than that given in Table 2.12.2.3.

Choice of Rated Voltage of Cables for AC Systems Table 2.12.2.3

Rated (between phases) voltage (kV) of Systems	Rated voltage U_0/U (kV) of cables	
	Category I distribution system	Category II distribution system
≤0.25	0.15/0.25	0.15/0.25
≤1.0	0.6/1.0	0.6/1.0
≤3.0 (3.3)	1.8/3.0	3.6/6.0
≤6.0 (6.6)	3.6/6.0	6.0/10.0
≤10.0 (11)	6.0/10.0	8.7/15.0

Notes:

① Category I distribution system: Protective devices are to be provided to automatically disconnect the circuits having earth faults.

② Category II distribution system: In AC insulation systems or in AC systems with high-resistance earthed neutral, circuits having earth faults are not to be automatically disconnected.

2.12.3 Choice of protective covering

2.12.3.1 Cables are to be provided with appropriate sheath that satisfies the fluid resistance requirements according to their installation locations. For example, cables permanently fitted on decks exposed to the weather, in bathrooms, cargo holds, refrigerated spaces, machinery spaces or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. The nature of the impervious sheath is to satisfy the requirements for environmental conditions.

2.12.3.2 When choosing different types of protective coverings, consideration is to be given to the mechanical actions to which each cable may be subjected during installation and in service. If the mechanical strength of the protective covering is considered insufficient, the cable is to be fitted in pipes or

conduits or trunking or otherwise protected.

2.12.3.3 All cables and wiring external to electrical equipment are to be at least of a flame-retardant type. In general, cables which have passed the test of bunched flame-retardant cables in accordance with acceptable standards① are to be used. Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards② are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables (see 2.12.10).

2.12.3.4 Where cables for services, required to be operable under fire conditions, including their supply cables, pass through high fire risk areas③, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following:

(1) Cables being of a fire resistant type④ complying with the requirements of 3.5.1.1 of this PART are installed and run continuously to keep the fire integrity within the high fire risk area, as shown in Figure 2.12.3.4.

(2) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

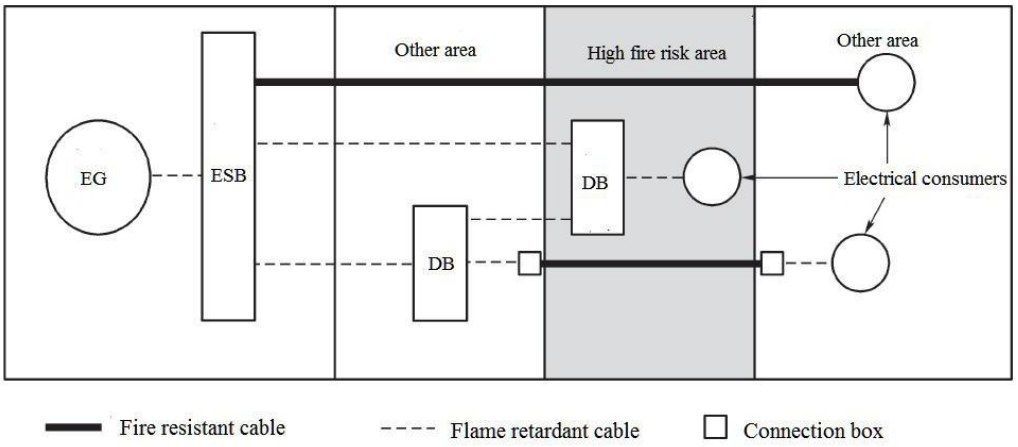


Figure 2.12.3.4 Cables for Services under Fire Conditions

2.12.3.5 Services required to be operable under fire conditions include:

(1) general emergency alarm system;
(2) fire detection and fire alarm system;
(3) fire extinguishing system and fire extinguishing medium release alarm;
(4) public address system;
(5) control and power systems of power operated fire doors and status indication systems for all fire doors;
(6) control and power systems of power operated watertight doors and their status indication systems;
(7) emergency lighting;
(8) low location lighting;
(9) remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion;
(10) emergency fire pump.

---

① Refer to IEC Publication 60332-3-22: Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A, or the equivalent standards.

② Refer to IEC Publication 60332-1-2: Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame and IEC 60332-2-2: Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame, or the equivalent standards.

③ The "high fire risk areas" are defined as follows:
(1) machinery spaces as defined in SOLAS Reg. II-2/3.30, excluding spaces having little or no fire risk as defined in SOLAS Reg. II-2/9.2.2.3.2.2 (10) (including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510);
(2) spaces containing fuel treatment equipment or other highly flammable substances;
(3) galley and pantries containing cooking appliances;
(4) laundry containing drying equipment;
(5) spaces as defined in SOLAS Reg. II-2/9.2.2.3.2.2(8), (12), and (14) for ships carrying more than 36 passengers.

④ Fire resistant type cables are to be easily distinguishable.

2.12.3.6 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and/or prime mover(s). When cables pass through high fire risk areas, the cables are to be of a fire resistant type.
2.12.3.7 Where necessary for particular applications, ISC may permit the use of special types of cables which do not comply with the requirements of 2.13.3.3 of this Section, such as radio frequency cables or digital computer information transmission system cables.
2.12.3.8 In passenger spaces and in service areas only halogen-free cables are to be used.

2.12.4 Determination of the cross-sectional area of conductors

2.12.4.1 The maximum continuous load carried by a cable is not to exceed its current rating corrected by correction factors. The diversity factor of the individual loads and the duration of the maximum load may be taken into account in estimating the maximum continuous load.
2.12.4.2 Cables supplying cargo winches, revolving cranes, windlasses and capstans are to be suitably rated for their duty.
2.12.4.3 The cross-sectional area of the conductors of equalizer leads for DC generators is not to be less than 50% of that of the main circuit cables. The cross-sectional area of neutral conductors in three-phase four-wire distribution systems is to be equal to at least 50% of that of phase conductors. If the cross-sectional area of phase conductors is 16 mm^2 or less, the cross-sectional area of the neutral conductors is to be the same.

2.12.5 Continuous service current rating

2.12.5.1 The maximum continuous load carried by a cable is not to exceed the values as given in Table 2.12.5.1.
Where a more precise evaluation of current rating has been carried out based on empirical or calculated data, details may be submitted to ISC for approval.

Current Ratings for Cables during Continuous Working Time
(Based on Ambient Temperature of 45℃) (A) **Table 2.12.5.1**

Nominal cross-section	Maximum rated conductor temp 90℃			Maximum rated conductor temp 95℃		
mm^2	Single core	2 cores	3 or 4 cores	Single core	2 cores	3 or 4 cores
1	18	15	13	20	17	14
1.5	23	20	16	26	22	18
2.5	30	26	21	32	27	22
4	40	34	28	43	37	30
6	52	44	36	55	47	39
10	72	61	50	76	65	53
16	96	82	67	102	87	71
25	127	108	89	135	115	95
35	157	133	110	166	141	116
50	196	167	137	208	177	146
70	242	206	169	256	218	179
95	293	249	205	310	264	217
120	339	288	237	359	305	251
150	389	331	272	412	350	288
185	444	377	311	470	400	329
240	522	444	365	553	470	387
300	601	511	421	636	541	445

2.12.5.2 The continuous service of cables required in this Section is the service that the continuous service period of current with constant loading are three times longer than the time constant of cables, i.e. more than the critical duration (see Figure 2.12.5.2).

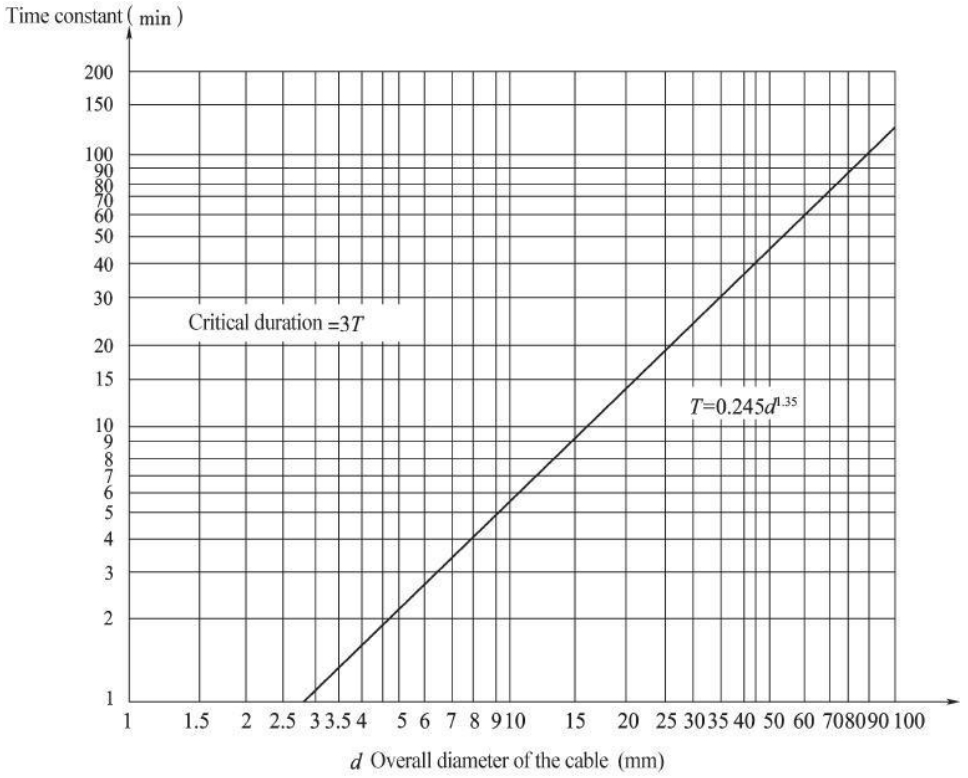


Figure 2.12.5.2 Time Constant of Cables

2.12.6 Correction factors for current rating

2.12.6.1 Correction factors for different ambient temperatures.

When it is known that the ambient temperature is different from 45℃, correction factors given in Table 2.12.6.1 are to be applied.

Correction Factor for Ambient Temperature **Table 2.12.6.1**

Ambient temp. (℃) / Max. operating conductor temp. (℃)	35	40	45	50	55	60	65	70	75	80	85
60	1.29	1.15	1.00	0.82	–	–	–	–	–	–	–
65	1.22	1.12	1.00	0.87	0.71	–	–	–	–	–	–
70	1.18	1.10	1.00	0.89	0.77	0.63	–	–	–	–	–
75	1.15	1.08	1.00	0.91	0.82	0.71	0.58	–	–	–	–
80	1.13	1.07	1.00	0.93	0.85	0.76	0.65	0.53	–	–	–
85	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50	–	–
90	1.10	1.05	1.00	0.94	0.88	0.82	0.74	0.67	0.58	0.47	–
95	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45

2.12.6.2 Correction factors for bunched cables

(1) For cables laid in one of the following manners and so arranged as to ensure free circulation of cooling air around each bunch, the current ratings in Table 2.12.5.1 may be directly applied:

① not more than six cables bunched together on cable trays, in cable conduits, pipes or trunking;

② more than six cables arranged in the following manners:

distance between any two sextuplets is at least equal to the diameter of the thickest cable

○○○○○○ ○○○○○○ ○○○○○○

or distance between any two triplets both horizontally and vertically is at least equal to the diameter of the thickest cable

○○○ ○○○ ○○○

○○○ ○○○ ○○○

(2) Where more than six cables, which may be expected to operate simultaneously at their rated capacity, are laid close together in a cable bunch[①] in such a way that there is an absence of free air circulation around

① Cables are said to be bunched when two or more are contained within a single conduit, trunking or duct, or if not enclosed, are not separated from each other.

them, a correction factor of 0.85 is to be applied. When a corrector factor of 0.85 is used, care is to be taken that there are in general not more than two layers in each cable bunch.

2.12.6.3 Correction factors for non-continuous service

(1) For half-hour and one-hour services, the corresponding correction factors given by Figure 2.12.6.3(1) may be applied. These correction factors are applicable only if the periods of no load are longer than the critical duration given in Figure 2.12.5.2.

(2) For repetitive short-time services, the corresponding correction factors given in Figure 2.12.6.3(2) may be applied.

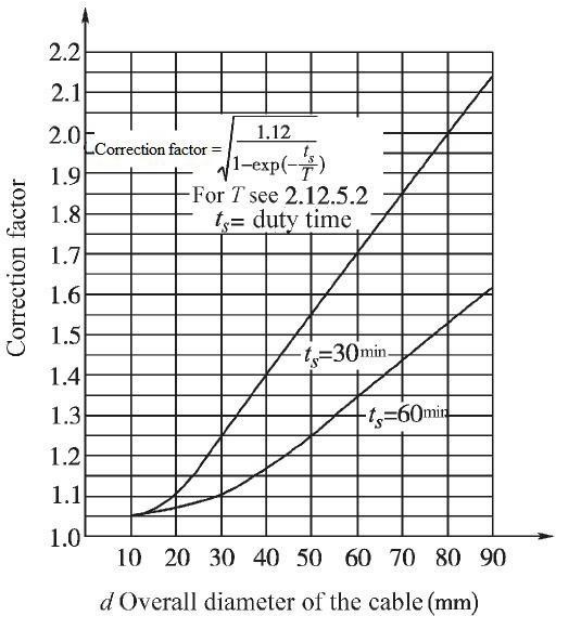
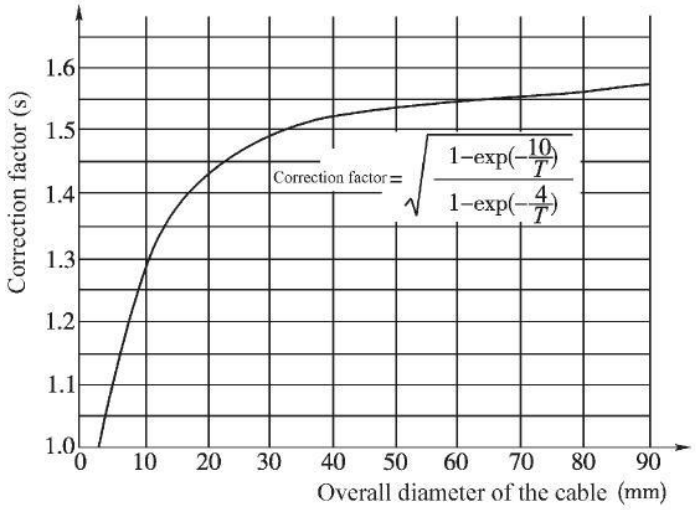


Figure 2.12.6.3(1) Correction Factors for Half-Hour and One-Hour Services



Note: The correction factors given in the Figure are roughly calculated for periods of 10 min, with a constant load for 4 min and without load for 6 min.

Figure 2.12.6.3(2) Correction Factors for Repetitive Short-Time Services

2.12.7 Parallel connection of cables

2.12.7.1 Parallel connection of cables will be permitted only for cables having a cross section of 10 mm^2 or more. The current rating of cables connected in parallel is the sum of the current ratings of all parallel conductors provided the cables have equal impedance, cross section and rated maximum operating conductor temperature.

2.12.8 Short-circuit capacity

2.12.8.1 Cables and their insulated conductors are to be capable of withstanding the mechanical and thermal effects of the maximum short-circuit.

2.12.9 Cable runs

2.12.9.1 Cable runs are to be, as far as possible, straight and accessible for inspection.

2.12.9.2 Cable runs are to be so arranged as to avoid the harmful effects from moisture or condensed water.

2.12.9.3 Cable runs are to be, as far as possible, away from the sources of heat such as boilers, hot pipes, resistors, etc., and are to be protected against mechanical damage.

2.12.9.4 Cables are not to be installed across expansion joints in any structure. Where this is unavoidable, a loop of cable having a length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

2.12.9.5 Cables having insulating materials with different maximum rated conductor temperatures are not to be bunched together. Where this is unavoidable, the cables are to be so installed that no cable reaches a temperature higher than that permitted for the cable with the lowest temperature rating in the bunch.

2.12.9.6 Cables having a protective covering or sheathing which may damage the covering or sheathing of other cables are not to be bunched together.

2.12.9.7 Where the main bus-bar is subdivided into two or more independent sections in accordance with the requirements of 2.1.1.1(5) of this Chapter, cables from different main generators to main switchboards are to follow at least two routes which are to be as far apart as practicable, for example from port and starboard or from different deck platforms.

2.12.9.8 Where a duplicate supply is required for essential electrical equipment, such as the two cables for the supply of the control box of navigation lights, the two cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.9 In the case of duplicated essential services, or systems which could operate as each other's stand-by for an essential function (such as duplicated power equipment of steering gears), the supply and any associated control cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.10 In passenger ships, distribution systems are to be so arranged that fire in any main vertical zone as defined in PART SIX of the Rules will not interfere with supply to services essential for safety in any other such zone. The requirement is considered satisfied if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

2.12.9.11 Cables serving essential services or emergency power equipment, emergency lighting and internal communications or signals used in an emergency are to be as far as practicable routed clear of galleys, laundries, machinery spaces and their casings and other high fire risk areas, except for supplying equipment in these spaces.

Where possible, these cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

2.12.9.12 Main cable runs and cables for the supply and control of essential services are to be kept away from the machinery and machinery parts① having an increased fire risk unless:

(1) the cables serve such installations;

(2) the cables are separated by a steel bulkhead or deck from such installations;

(3) the cables are of a fire-resisting type.

2.12.9.13 Where trunk cables are laid in concealed manner, the panelling in way of which is to be arranged for easy removal.

2.12.9.14 Cables are not to be directly embedded in the thermal or sound insulation made of combustible material. Where cables are separated by non-combustible covering, they may be laid in the insulation, but the load carried is to be reduced accordingly.

2.12.9.15 The arrangement and run of fire resistant cables are to be in compliance with the following:

(1) Cables are to be so arranged that the loss of these services due to a localized fire at any one area or zone specified in 2.12.3.4 of this Section is minimized.

(2) Cables are to be run as straight as is practicable.

2.12.9.16 Cables of intrinsically safe circuits are to be laid apart from those for non-intrinsically safe circuits, e.g. neither bundled together or placed in the same casing or pipe, nor fixed by common clamps. The outer sheath of the cable is to be coloured blue or alternatively black with clearly visible blue stripes. Intrinsically safe circuits of "ia" and "ib" class are not to be run in the same cable and to have their own separate cables.

2.12.10 Means to limit the propagation of fire along bunched cables

2.12.10.1 Where cables which have individually passed the test of a single flame-retardant cable in

① Machinery, machinery parts or equipment containing combustibles are considered to have an increased fire risk.

accordance with acceptable standards (see 2.12.3.3) are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables[①], as required in 2.12.10.2 to 2.12.10.4.

2.12.10.2 Fire dampers are to be provided (see Figure 2.12.10.2).

(1) Cables laid vertically in enclosed or semi-enclosed spaces are to be provided with fire dampers in the following locations:

① at every second deck or approximately 6 m, except cables installed within the fully-closed trunking;

② at cable entrances of main switchboard and emergency switchboard;

③ at cable entrances of engine control room;

④ at cable entrances of centralized control panels for propulsion machinery and essential auxiliary machinery;

⑤ at each end of the fully-closed cable duct.

(2) Cables laid horizontally in closed or semi-enclosed spaces are to be provided with fire dampers in the same locations required in (1), but the maximum spacing of fire dampers may be increased to 14 m.

(3) In the passageways having a height lower than the neck of a standing person within cargo holds and cargo areas, fire dampers can only be fitted on the boundaries of compartments.

2.12.10.3 The fire dampers are to be designed to meet the following requirements:

(1) The fire resistance of cables passing through fire stops must meet the requirements for class B-0 divisions.

(2) Fire dampers are to be made of steel plate with the thickness of at least 3 mm.

(3) Where cables are laid vertically in the non-fully-closed trunking, the fire damper is to cover the sectional area of the trunking.

(4) Where cables are laid open, the fire damper is to extend around to twice the maximum laying size of cables, but not to penetrate ceilings, decks, bulkheads or the rigid sidewall of trunking.

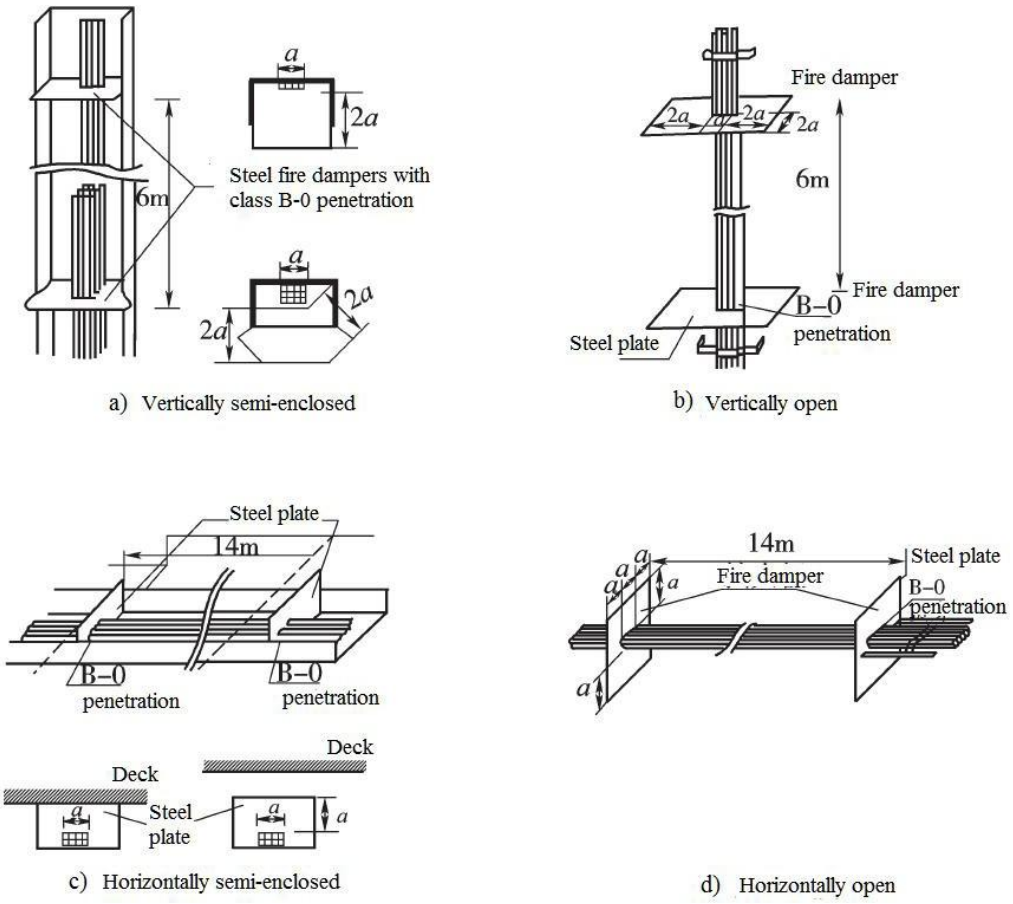


Figure 2.12.10.2 Locations of Fire Dampers

2.12.10.4 Instead of the fire dampers required above, installed cable bunches may be provided with

① The bunched cables mentioned here are 5 or more cables from machinery spaces and high fire hazard spaces and more than 10 cables from other spaces are laid close together in the cable trunking.

flameproof coating:
(1) over a length of 1 m in every 14 m for horizontal cable runs (see Figure 2.12.10.4a);
(2) over the entire length of vertical cable runs (see Figure 2.12.10.4b).

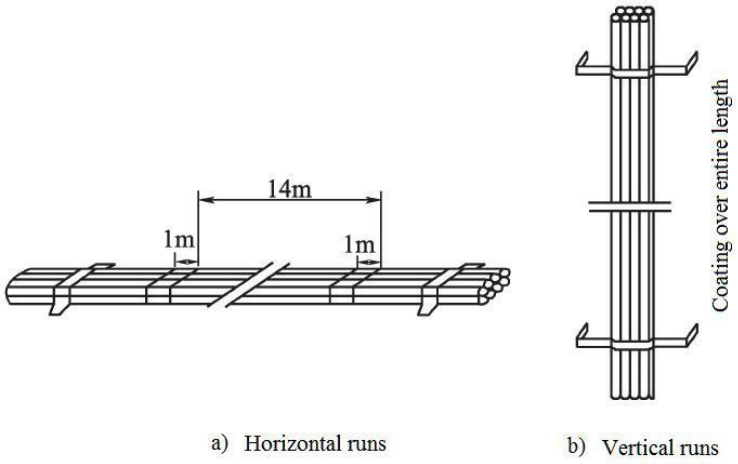


Figure 2.12.10.4 Location of Flameproof Coating

2.12.11 Mechanical protection of cables

2.12.11.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casings or enclosed in steel conduits, unless the protective sheathing of cables is sufficient to withstand the possible damage.

2.12.11.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured.

2.12.11.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

2.12.11.4 Where cables are placed underneath the floor plates in machinery spaces, reliable precautions are to be taken to prevent such cables from being soaked in oil or water, or being exposed to mechanical damage.

2.12.12 Radius of bend

2.12.12.1 The minimum internal radius of bend of installed cables is to be generally in accordance with the manufacturer's recommendations, and is not to be less than the provisions of Table 2.12.12.1(1) and Table 2.12.12.1(2).

Minimum Internal Radius of Bends in Cables Rated up to 1.8/3kV Table 2.12.12.1(1)

Cable construction		Overall diameter of cable *D* (mm)	Minimum internal radius of bend *F*
Insulation	Outer covering		
Thermoset material (circular copper conductor)	Not armoured or not braided	≤ 25	4*D*
		> 25	6*D*
	Metal sheathed, braided or armoured	Any	6*D*
	Metal thread armoured, metal strip armoured	Any	6*D*
	Synthetic polyester/metal sheathed slice or combined sheathed	Any	8*D*
Thermoset material (circular copper conductor)	Any	Any	8*D*

Minimum Internal Radius of Bends in Cables Rated at 3.6/6.0(7.2) kV and above
Table 2.12.12.1(2)

Cable construction	Overall diameter of cable *D* (mm)	Minimum internal radius of bend *F*
Single core cable	Any	12*D*
3-core cable	Any	9*D*

2.12.13 Securing of cables

2.12.13.1 Cables are to be effectively supported and secured with the exception of cables for portable appliances and of those installed in pipes, conduits, trunking or special casings.

2.12.13.2 Clips or straps are to be robust and are to have a sufficient surface area and a certain shape so that the cables may remain tight without their covering or sheathing being damaged.

2.12.13.3 Clips, supports and accessories are to be made of corrosion-resistant material or suitably corrosion inhibited before erection.

2.12.13.4 The distance between supports is to be suitably chosen according to the type of cables and the possible vibration, and is generally to be in accordance with Table 2.12.13.4.

External Diameter of Cable and Distance between Supports Table 2.12.13.4

External diameter of cable (mm)		Distance between supports (mm)	
Exceeding	Not exceeding	Non-armoured cables	Armoured cables
–	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	–	400	450

2.12.13.5 When cables are fixed by means of non-metallic clips or straps, and are not laid on top of horizontal cable trays or supports, suitable metal cable clips or straps are to be added at regular distances not greater than 1 m in order that in the event of a fire, cables are prevented from falling and causing an injury to personnel or an obstruction to any escape route.

2.12.14 Penetration of bulkheads and decks by cables

2.12.14.1 Penetration of watertight bulkheads or decks may be carried out with either individual watertight glands or with packed watertight boxes carrying several cables, provided that the watertight integrity of the bulkheads or decks is to be maintained.

2.12.14.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material.

If the steel is 6 mm or more in thickness, adequately rounded edges may be accepted as the equivalent of bushing.

2.12.14.3 Penetration of bulkheads and decks requiring a certain fire integrity is to be so effected as to ensure that the required fire integrity is not impaired.

2.12.14.4 Cables passing through decks are to be protected by deck tubes or ducts having a suitable height.

2.12.14.5 Materials used for glands and bushings are to be such that there is no risk of corrosion to cables or hull structures.

2.12.14.6 Where rectangular holes are cut in bulkheads or structural steel, the corners of the holes are to be radiused.

2.12.14.7 Where a cable transit seal system is used, a register is to be developed according to Appendix 3, Chapter 4, PART ONE of the Rules.

2.12.15 Installation of cables in pipes, conduits or trunking

2.12.15.1 When cables are installed in metal pipes, conduits or trunking, the following requirements are to be complied with:

(1) The internal surfaces of the pipes, conduits or trunking are to be smooth and protected against corrosion.

(2) Provision is to be made at the ends of pipes, conduits or trunking so as to protect the sheathing or covering of cables from being damaged.

(3) The internal sectional area and radius of bend of pipes or conduits are to be such as to permit easy drawing in and out the cables contained therein; the internal radius of bend of pipes or conduits is not to be less than that allowed for cables, provided that for pipes equal to or above 63 mm in external diameter, the internal radius of bend is not less than twice the external diameter of the pipe.

(4) The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-sectional area of the pipe) is not to exceed 0.4.

(5) Pipes, conduits or trunking are to be effectively earthed.

(6) Pipes, conduits or trunking are to be so arranged that water will not accumulate inside them (consideration being given to possible condensation).

(7) If necessary, ventilation openings are to be provided, preferably at the highest and lowest points, so as

to permit air circulation and to prevent possible accumulation of water at any part of the pipes, conduits or trunking. This may be done only if the fire risk will not be increased thereby.
(8) Expansion joints are to be provided where necessary for long pipe run.
2.12.15.2 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.
2.12.15.3 Cables used for cold cathode luminous discharge lamps are not to be installed in metal conduits unless protected by metal screen.

2.12.16 Installation of cables in refrigerated spaces
2.12.16.1 Cables not serving refrigerated spaces are not to pass through such spaces. Cables installed in refrigerated spaces are to have an impervious sheath and are to be protected against mechanical damage. If an armoured cable is used, the armour is to be protected against corrosion by a further moisture-resisting covering.
2.12.16.2 Cables are to be run in the open in refrigerated spaces.
2.12.16.3 Metal supports used for securing the cables are to be galvanized or otherwise protected against corrosion.

2.12.17 Relief of tension
2.12.17.1 Cables are to be so installed that the tension stress applied to them either by their own weight or for any other reason is minimized. This is particularly important for cables of small cross-sections and for cables laid vertically or in vertical pipes.

2.12.18 Electrodynamic forces
2.12.18.1 In order to guard against the effects of electrodynamic forces in the event of short-circuit, single-core cables are to be firmly fixed and the strength of supports is to be sufficient to withstand the electrodynamic forces corresponding to the prospective short-circuit currents.

2.12.19 Installation of single-core cables for alternating current
2.12.19.1 For AC power systems, two-core or multi-core cables are to be used as far as practicable. Where it is necessary to use single-core cables for circuits rated in excess of 20 A, the following requirements are to be complied with:
(1) Cables are to be either non-armoured or armoured and covered with non-magnetic material.
(2) Cables belonging to the same circuit are to be contained in the same pipe, conduit or trunking. Cable clips are to include cables of all phases of a circuit, unless the clips are of non-magnetic material.
(3) In the installation of two, three or four single-core cables forming respectively single-phase, three-phase, or three-phase four-wire circuits, the cables are to be as far as possible in contact with one another. In any event, the distance between adjacent cables is not to be greater than one cable diameter.
(4) When it is necessary to install single-core cables of current rating greater than 250 A near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the single-core cables belonging to different phases are installed in trefoil formation.
(5) Magnetic material is not to be placed between single-core cables of a group for the same circuit. Where cables pass through steel plates, all conductors of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless single-core cables belonging to different phases are installed in trefoil formation.
(6) In order to equalize to some degree the impedance of three-phase circuits of considerable length consisting of single-core cables having a cross sectional area of 185 mm^2 or over, the phases are to be transposed at regular intervals of not exceeding 15 m. Alternatively, the three single-core cables of different phases may be installed in a trefoil formation. The above precautions are, however, not necessary when the length of the run is less than 30 m.
(7) In circuits with several single-core cables in parallel for each phase, all cables are to follow the same route and have the same cross-sectional area.
In addition, cables belonging to the same phase are, as far as practicable, to be alternated with those of other phases so that an unequal division of current is avoided. For instance, in the case of six cables for each phase, the correct dispositions are as shown in Table 2.12.19.1.

Disposition of Cables **Table 2.12.19.1**

Cables in parallel for each phase	1-layer disposition	2-layer disposition
2	ABC CBA	ABC CBA
3		ABCA BCABC
4		ABCABC CBACBA
5		ABCABCA BCABCABC
6		ABCABCABC CBACBACBA

2.12.20 Installation of cables with respect to prevention of electromagnetic interference

2.12.20.1 In order to minimize the effects of unwanted electromagnetic interference, cables are to be installed in accordance with the relevant standards① accepted by ISC.

2.12.21 Earthing of metal protective coverings of cables

2.12.21.1 The earthing of metal protective coverings (braid or armour) of cables is to be in accordance with the relevant requirements of Section 3, Chapter 1 of this PART.

2.12.22 Cable ends

2.12.22.1 The ends of all conductors of a cross-sectional area greater than 4 mm^2 are to be fitted with soldered sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

2.12.22.2 The temperature of cable sockets and terminals is, in general, not to exceed the maximum operating temperature of insulated cables.

2.12.22.3 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and dynamic effects of short-circuit currents.

2.12.23 Joints and tappings

2.12.23.1 Cable runs are normally not to include joints. If a joint is necessary in the case of repair or sectional construction of the ship, the joint is to be such that the electrical continuity, insulation, mechanical strength and protection, earthing and fire-resisting or flame-retardant characteristics are not inferior to those required for the cables.

2.12.23.2 Tappings are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or bus-bars of dimensions appropriate to the current rating.

2.12.23.3 Joints and tappings are to be clearly marked.

2.12.24 Connection boxes

2.12.24.1 Connection boxes are to be made of flame-retardant material. Mountings of live parts are to be robust, durable, flame-retardant and moisture-resistant, having permanently insulation resistance with high dielectric strength.

2.12.24.2 Live parts within the box are to be suitably spaced or provided with shielding by flame-retardant insulating material so that a short-circuit will not occur between conductors of different polarity or between conductors and earthed metal.

2.12.24.3 Each connection box is to be provided with a nameplate indicating its purpose or a durable no. mark corresponding to the wiring diagram. Where the connection boxes are installed in a concealed manner, the panelling in way of the boxes is to be arranged for easy removal.

2.12.25 Cable trays/protective casings made of plastic materials

2.12.25.1 Cable trays/protective casings② made of plastic③ materials are to be type tested in accordance with Appendix 2 of this PART − "Type Approval Procedure for Cable Trays/Protective Casings Made of Plastic Materials".

---

① Refer to IEC Publication 60533: Electrical and Electronic Installations in Ships – Electromagnetic Compatibility, or the relevant requirements in relevant standards.

② "Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

③ "Plastic" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.

2.12.25.2 Cable trays/protective casings made of plastic materials are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.
2.12.25.3 The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer's recommendation nor in excess of spacing at the SWL test. In general the spacing is not to exceed 2 m. The selection and spacing of cable tray/protective casing supports are to take the following into account:
(1) cable trays/protective casings' dimensions;
(2) mechanical and physical properties of their material;
(3) mass of cable trays/protective casings;
(4) loads due to weight of cables, external forces, thrust forces and vibrations;
(5) maximum accelerations to which the system may be subjected;
(6) combination of loads.
2.12.25.4 The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

Section 13 LIGHTNING PROTECTION

2.13.1 Protection against primary structural damage

2.13.1.1 A protective system need not be fitted to a ship of metallic construction where a low resistance path to earth will be inherently provided by masts, structural members and the hull.
2.13.1.2 A protective system is to be fitted to any ship having a substantial number of non-metallic structural members.
2.13.1.3 The protective system is to be comprised of air terminal, down conductor and earth termination.
2.13.1.4 Metallic masts and metallic structural members may form part or all of any protective system.
2.13.1.5 The metal rigging, such as stays, shrouds, etc., are to be bonded to the protective system.
2.13.1.6 Joints in down conductors are to be accessible and be located or protected so as to minimize accidental damage. They are to be made by means of copper rivets or clamps. Clamps may be of copper or of copper alloy and are to preferably be of the serrated contact type and effectively locked. No connection is to be dependent on a soldered joint.
2.13.1.7 The resistance between air terminals and earth terminations is not to exceed 0.02 Ω.
2.13.1.8 Suitable means are to be provided to enable ships when in dry dock, or on a slipway, to have their protective systems or metal hull connected to an efficient earth on shore. Connecting cables to the shore earth is to be external to the earth throughout their length.
2.13.1.9 Air terminals of the protective system are to comply with the following requirements:
(1) An air terminal is to be fitted to each non-metallic mast.
(2) Air terminals are to be made of copper or copper alloy conducting bar of not less than 12 mm diameter, and are to project at least 300 mm beyond the top of the mast. Other materials may be used, for example stainless steel or aluminium alloys, or steel bar effectively protected against corrosion, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(3) Vent outlets for flammable gases located at or near the top of masts on tankers are to be protected by air terminals which extend at least 2 m above the vent outlet. A steel mast may serve as the air terminal if it extends 2 m above the outlet.
2.13.1.10 Down conductors of the protective system are to comply with the following requirements:
(1) Down conductors are to be made of copper, or copper alloy tape or cable. Cable is preferred as both the insulation and the circuit shape inhibit surface discharge. Other materials may be used, for example stainless steel or aluminium alloys, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(2) Down conductors of copper are to have a minimum cross-section of 70 mm^2, be firmly secured to the structure and be run as straight as possible between the air terminal and the earth termination. Bends, where necessary, are to have a minimum radius of at least 10 times the equivalent diameter of the conductor.
2.13.1.11 The ends of down conductors are to be reliably bonded to the earth terminations of the metallic construction of the ship nearby. Where necessary, measures are to be taken for preventing electrochemical corrosion.

2.13.2 Protection against secondary damage

2.13.2.1 On all ships, equipment is to be so installed as to minimize the effect of secondary damage caused by lightning to the electrical system.
2.13.2.2 Metallic enclosures are to be reliably earthed. Particular attention is to be paid to navigation lights and other equipment at the top of masts and on other elevated structures.
2.13.2.3 Cable screens or armour, though normally earthed for signal interference suppression, are not to provide the sole lightning path to earth for equipment. Separate earthing, as required in 2.13.2.2, is to be provided.
2.13.2.4 The formation of cable loops, or metallic loops such as pipework, in proximity to down conductors of the protective system required in 2.13.1.2 is to be avoided. Cables in close proximity to down conductors are to be installed in metal pipes.
2.13.2.5 Cables along decks are to be installed close to the deck and advantage is to be taken of the screening effect of earthed metallic structures near to or above the cable runs, for examples handrails, pipes, etc.
2.13.2.6 Means are to be provided for the discharging to earth of any lightning energy that may be induced in for example radio and navigational equipment antennas. Consideration is to be given to installing devices such as spark gaps or surge diverters to provide protection from voltage transients.

Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS

2.14.1 General requirements

2.14.1.1 This Section applies to AC three-phase systems with nominal voltage (voltage between phases) exceeding 1 kV. If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.
2.14.1.2 The nominal system voltage is not to exceed 15 kV. Where necessary for special application, higher voltages may be accepted by ISC.
2.14.1.3 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2.14.2 System design

2.14.2.1 The distribution of high-voltage electrical installations is to comply with the following:
(1) It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.
Services which are duplicated are to be divided between the sections.
(2) For earthed neutral systems in case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.
It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.
(3) Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.
(4) All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.
(5) In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each separate section of the main switchboard.
2.14.2.2 The degrees of protection provided by enclosures for the high-voltage electrical equipment is to be appropriate to the location of installation, as a minimum in compliance with the requirements of Table 1.3.2.2 of this PART and in addition the following:
(1) The degree of protection by enclosures for rotating electrical machines is to be at least IP23. The degree of protection of terminals is to be at least IP44. For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

(2) The degree of protection by enclosures for transformers is to be at least IP23. For transformers installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
For transformers not contained in enclosures, 2.14.7.1 of this Section is to be complied with.
(3) The degree of protection of metal enclosed switchgear, control gear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
2.14.2.3 The air clearances and creepage distances are to comply with the following:
(1) In general, for non-type-tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are not to be less than those specified in Table 2.14.2.3.
Where intermediate values of nominal voltages are accepted, the next higher air clearance is to be observed. In the case of smaller clearances, appropriate voltage impulse test is to be applied.

Minimum Air Clearances **Table 2.14.2.3**

Nominal voltage (kV)	Minimum air clearance (mm)
3 (3.3)	55
6 (6.6)	90
10 (11)	120
15	160

(2) Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with IEC publication 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.
2.14.2.4 For protection of the high-voltage electrical system, the following special requirements are to be complied with:
(1) Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and automatically de-excite the generator.
In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.
(2) Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems (a system is defined effectively earthed when the earthing factor① is lower than 0.8), provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems (a system is defined non-effectively earthed when the earthing factor is higher than 0.8), where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.
(3) Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.
(4) Voltage transformers are to be provided with overload and short circuit protection on the secondary side.
(5) Fuses are not to be used for overload protection.
(6) Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:
① direct earthing of the lower voltage system;
② appropriate neutral voltage limiters;
③ earthed screen between the primary and secondary windings of transformers.

2.14.3 Rotating machinery

2.14.3.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.
2.14.3.2 Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.
If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.
2.14.3.3 In addition to the tests normally required for rotating machinery, a high frequency high voltage

① Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/\sqrt{3}$ and 1.

test in accordance with acceptable standard(s)[①] is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

2.14.4 Power transformers

2.14.4.1 Dry type transformers are to comply with acceptable standard(s)[②], and liquid cooled transformers are also to comply with acceptable standard(s)[③].

2.14.4.2 Oil immersed transformers are to be provided with the following alarms and protections:

(1) liquid level (Low) – alarm;

(2) liquid temperature (High) – alarm;

(3) liquid level (Low) – trip or load reduction;

(4) liquid temperature (High) – trip or load reduction;

(5) gas pressure relay (High) – trip.

2.14.5 Cables

2.14.5.1 Cables are to be constructed in accordance with acceptable standards[④].

2.14.6 Switchgear and control gear assemblies

2.14.6.1 Switchgear and control gear assemblies are to be constructed according to acceptable standards[⑤].

2.14.6.2 Switchgear and control gear assemblies are to be constructed in accordance with the following requirements:

(1) Switchgear is to be of metal-enclosed type or of the insulation-enclosed type in accordance with acceptable standard(s)[⑥].

(2) Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

(3) The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered. Shutters are to be clearly marked for incoming and outgoing circuits. This may be achieved with the use of labels or colours.

(4) For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

(5) Switchgear and controlgear assemblies are to be internal arc classified (IAC). Where switchgear and controlgear assemblies are accessible by authorized personnel only, Accessibility Type A is sufficient (refer to IEC 62271-200; Annex AA; AA 2.2). Accessibility Type B is required if accessible by non-authorized personnel. Installation and location of the switchgear and controlgear assemblies are to correspond with their internal arc classification and classified sides (F, L and R).

2.14.6.3 Requirements for auxiliary systems

(1) If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two consecutive operations of all the components. However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

(2) When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more

---

① Refer to IEC Publication 60034-15 Rotating electrical machines – Part 15: Impulse voltage withstand levels of rotating AC machines with form-wound stator coils, or other equivalent standards.

② Refer to IEC Publication 60076-11 Dry-type power transformers, or other equivalent standards.

③ Refer to the applicable Parts of the IEC 60076 Series, or other equivalent standards.

④ Refer to IEC Publication 60092-353 Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV and IEC Publication 60092-354 Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7.2 kV) up to 30 kV (Um = 36 kV).

⑤ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, or other equivalent standards.

⑥ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, and compliance with IEC Publication 62271-201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

than one generator set and/or set of essential services. Where necessary, one source of supply is to be from the emergency source of electrical power for the start-up from dead ship condition.

2.14.6.4 A power-frequency voltage test is to be carried out on any switchgear and control gear assemblies. The test procedure and voltages are to be according to acceptable standard(s)[①].

2.14.7 Installation

2.14.7.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regards the high-voltage electrical equipment installed outside a.m. spaces, the similar marking is to be provided.

An adequate, unobstructed working space is to be left in the vicinity of high voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling/deckhead above is to meet the requirements of the internal arc classification[②].

2.14.7.2 Run of high-voltage cables is to comply with the following:

(1) In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

(2) High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same duct or pipe, or, in the same box. Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in 2.14.2.3(1) of this Section. However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV and less.

(3) High-voltage cables, in general, are to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic casings effectively bonded to earth.

(4) Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials. High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc.).

(5) High-voltage cables are to be readily identifiable by suitable marking.

(6) Before a new high voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test is then repeated. The voltage withstand test is to be carried out in accordance with the following methods:

① For cables with rated voltage above 1.8/3 kV (U_m[③]=3.6 kV) an a.c. voltage withstand test may be carried out upon advice from high voltage cable manufacturer. One of the following test methods may be used: test for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen/sheath, or test for 24 h with the normal operating voltage of the system; alternatively, a d.c. test voltage equal to 4 U_0 may be applied for 15 min.

② For cables with rated voltage up to 1.8/3 kV (U_m=3.6 kV) a d.c. voltage equal to 4 U_0 is to be applied for 15 min.

---

① Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV – Part 7: Routine test, or other equivalent standards.

② Refer to 6.2.5 of IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

③ *U*m is the maximum value of the "highest system voltage" for which the equipment may be used. Highest system voltage is the highest value of voltage which occurs under normal operating conditions at any time and at any point on the system. It excludes voltage transients, such as those due to system switching, and temporary voltage variations.

Section 15 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY

Electrical propulsion machinery is to comply with the applicable requirements of this PART and the requirements of Chapter 15, PART EIGHT of the Rules.

Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS

2.16.1 General requirements

2.16.1.1 Electrical installations on tankers carrying crude oil and oil products are to comply with the provisions of this Section and other provisions of this PART as appropriate.

2.16.1.2 The classification of typical hazardous areas of oil tankers is carried out in accordance with zone 0, zone 1 and zone 2 based on the provisions of IEC60092-502 in this Section. For areas or spaces not mentioned in this Section, the classification of hazardous areas may be carried out in accordance with the principles given in IEC60079-10-1.

2.16.1.3 Electrical equipment and cables are, in principle, not to be installed in any hazardous areas. If it is impracticable to avoid doing so, the relevant provisions of this Section are to be complied with.

2.16.2 Distribution systems

2.16.2.1 The following distribution systems may be used:

(1) DC, two-wire, insulated;

(2) AC, single-phase, two-wire, insulated;

(3) AC, three-phase, three-wire, insulated.

2.16.2.2 No direct electrical connection is allowed between power networks operating at different voltages.

2.16.2.3 All circuits of generation, supply and distribution systems are not to be earthed, and hull return system is not permitted with the following exceptions:

(1) intrinsically safe circuits;

(2) power supplied control circuits and instrumentation circuits where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions;

(3) limited and locally earthed systems, provided that any possible resulting current does not flow directly through any of the hazardous spaces;

(4) AC distribution systems with 1,000 V (root mean square) and over between phases, provided that any possible resulting current does not flow directly through any of the hazardous spaces.

2.16.3 Cables and their installation

2.16.3.1 All cables, other than those of intrinsically safe circuits, installed in zone 0 and zone 1, are to be provided with an impervious sheath in combination with braiding or other metallic covering.

2.16.3.2 Cables of intrinsically safe circuits are to have a metallic shielding with at least an impervious sheath.

2.16.3.3 Where cables are subject to lengthy immersion in the cargo, the construction of the cables is to be such as to withstand the substances to which they can be exposed, or the cables are to be enclosed in casings (such as metallic pipes) capable of withstanding such substances.

2.16.3.4 Where corrosion may be expected, an impervious sheath is to be applied over the metal braid or armour of the cable.

2.16.3.5 Where cables pass through gastight bulkheads or decks separating hazardous areas from non-hazardous areas, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

2.16.3.6 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be so installed as to avoid strain or chafing and due allowance is to be made for expansion or working of the structure. Where ring-type expansion bends are fitted, they are to be accessible for maintenance.

2.16.3.7 Cables installed in pump rooms are to be suitably protected against mechanical damage.

2.16.3.8 Flexible cables or wires for portable electrical appliances are not to pass through hazardous areas or spaces, with the exception of flexible cables or wires of intrinsically safe type.

2.16.4 Electrical equipment in hazardous areas

2.16.4.1 For electrical equipment installed in hazardous areas, the appropriate certified explosion-proof equipment is to be selected in accordance with the category of hazardous areas, and the explosion group and temperature class are not to be lower than II A T3.

2.16.4.2 The following equipment is allowed to be installed in zone 0:

(1) certified intrinsically-safe apparatus of category "ia";

(2) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category "ia", not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(3) submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.

2.16.4.3 The following equipment is allowed to be installed in zone 1:

(1) electrical equipment specified in 2.16.4.2 of this Section;

(2) certified intrinsically-safe apparatus of category "ib";

(3) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category "ib", not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(4) certified flameproof (type "d");

(5) certified pressurized (type "p");

(6) certified increased safety (type "e");

(7) certified encapsulated (type "m");

(8) certified sand filled (type "q");

(9) certified specially (type "s")[①];

(10) anodes or electrodes of an impressed current cathodic protection system, or transducers such as those for depth-sounding or log systems, provided that such fittings are housed within a gastight enclosure, and are not located adjacent to a cargo tank bulkhead;

(11) through runs of cable.

2.16.4.4 The following equipment is allowed to be installed in zone 2:

(1) electrical equipment specified in 2.16.4.3 of this Section;

(2) non-sparking electrical equipment "n";

(3) the type which ensures the absence of sparks and arcs and of "hot spots" during its normal operation.

2.16.4.5 Transmitting aerials and any associated riggings are to be sited well clear of gas and vapour outlets.

2.16.4.6 For the electrical equipment permitted in hazardous areas or spaces, all switches and protective devices are to be capable of interrupting all poles or phases and are to be located in a non- hazardous area or space. Such equipment, switches and protective devices are to be clearly and durably labelled for identification purposes.

2.16.5 Earth connection and static electricity protection

2.16.5.1 The metal casings of all electrical equipment in any hazardous areas or spaces, regardless of the working voltage, are to be reliably earthed.

2.16.5.2 Cargo tanks, process plants and piping systems are to be earthed in accordance with 1.3.4.12 of this PART for the control of static electricity.

2.16.5.3 All rigging is to be effectively bonded to ship's hull.

2.16.6 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃

2.16.6.1 Zone 0 is to include the following areas or spaces:

(1) cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks;

(2) interior spaces containing the pipes and equipment containing cargo oil.

2.16.6.2 Zone 1 is to include the following areas or spaces:

(1) cofferdams and ballast tanks adjoining cargo tanks;

(2) cargo pump rooms and the mechanical ventilation is to comply with the following requirements:

① audible and visual alarms are to be given at a manned location in case of failure of the mechanical

---

① Where explosion-proof types (flameproof, increased safety, intrinsically-safe, pressurized, oil filled, sand filled, encapsulated and non-sparking) not included in the special standards are used for electrical equipment, they may be treated as electrical equipment certified specially (type "s").

ventilation in the cargo pump room;

② actions are to be taken to restore ventilation immediately after failure of the mechanical ventilation;

③ where the mechanical ventilation can not be restored for an extended period, the remaining electrical equipment other than those mentioned below is to be capable of being disconnected outside of hazardous areas and provided with means against unauthorized re-connections:
(a) intrinsically safe equipment;
(b) flameproof lighting;
(c) general emergency alarm sounder of flameproof type, without internal sparking contacts;

④ where the mechanical ventilation has been stopped for an extended period or it is initially used, the cargo pump room is to be purged for at least five air changes before connecting the electrical equipment (except the intrinsically safe equipment, flameproof lighting and general emergency alarm sounder of flameproof type);

(3) enclosed or semi-enclosed spaces immediately above cargo tanks (e.g. 'tween-deck spaces) or having bulkheads above and in line with cargo tank bulkheads;

(4) spaces other than cofferdams adjoining to and below the top of a cargo oil tank (e.g. trunks, passageways and general cargo holds), and double bottom and pipe tunnels below cargo tanks;

(5) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet[①], cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(6) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet;

(7) areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;

(8) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck;

(9) areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(10) compartments for cargo hoses;

(11) enclosed or semi-enclosed spaces in which pipes containing cargoes are located;

(12) fore peak tank and vent pipe openings as defined in 3.4.14.1, Chapter 3, PART SIX of the Rules.

2.16.6.3 Zone 2 is to include the following areas or spaces:

(1) areas of 1.5 m surrounding the open spaces or semi-enclosed spaces in zone 1 as specified in 2.16.6.2, if not otherwise specified in this standard;

(2) spaces 4 m beyond the area defined in 2.16.6.2(6);

(3) areas within 2 m beyond areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) the spaces forming an air-lock leading to zone 1;

(5) areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above the deck;

(6) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1;

(7) spaces forward of the open deck areas to which reference is made in 2.16.6.2(8) and 2.16.6.3(6) of this Section, below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:

① the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m from the foremost cargo tank and at least 10 m measured horizontally from any cargo tank outlet or gas or vapour outlet; and

② the spaces are mechanically ventilated.

---

① Such areas are sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

2.16.6.4 The hazards in some hazardous areas or spaces, e.g. those having direct openings into hazardous areas or spaces, may be reduced or these zones or spaces may be regarded as non-hazardous areas or spaces, provided that the arrangements of ventilation, pressurization, doors at openings, and other safety precautions are in compliance with relevant acceptable standards①.

2.16.7 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and not heated or heated to a temperature more than 15℃ below their flash point

2.16.7.1 The interiors of cargo tanks, slop tanks, any pipework of pressure/vacuum relief valve or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or handling flammable gas or vapour belong to zone 2.

2.16.8 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and heated to a temperature above their flash point or heated to a temperature within 15℃ of their flash point

2.16.8.1 Such tankers are to comply with the requirements for oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃, as specified in 2.16.6 of this Section.

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

2.17.1 General requirements

2.17.1.1 This Section applies to the electrical installations of ships with spaces for carrying vehicles with fuel in their tanks for their own propulsion.

2.17.1.2 The certified explosion-proof equipment required by this Section is to comply with the provisions of 1.3.3 of this PART, and the explosion group and temperature class are not to be lower than II A, T3.

2.17.2 Carriage of vehicles in special category spaces above the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with not less than 10 air changes per hour) of passenger ships and cargo ships

2.17.2.1 The electrical equipment fitted within a height of 450 mm above the vehicle deck or any platform on which vehicles are carried and within the exhaust ventilation trunking for the spaces is to be of certified safe type.

2.17.2.2 In spaces other than those specified in 2.17.2.1, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type.

2.17.3 Carriage of vehicles in special category spaces below the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with less than 10 air changes per hour) of passenger ships and cargo ships

2.17.3.1 The electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.

2.17.4 Carriage of vehicles in cargo spaces other than vehicle, special category or ro-ro spaces

2.17.4.1 On all ships, when vehicles with fuel in their tanks for their own propulsion are carried in cargo spaces other than vehicle, special category or ro-ro spaces, the requirements of SOLAS regulation II-2/20.2.1.2 are to be complied with.

2.17.5 Carriage of vehicles in open ro-ro spaces, open vehicle spaces and an area on weather deck of passenger ships and cargo ships

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART.

① See IEC publication 60092-502: Electrical installations in ships –Part 502: Tankers – Special Features.

Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

2.18.1 General requirements

2.18.1.1 The electrical installations onboard ships fitted with cargo spaces intended for carrying dangerous goods specified in 2.18.1.2 are to comply with the requirements of this Section and other applicable requirements of this PART.

2.18.1.2 Dangerous goods, for which safety measures are required with respect to the electrical equipment, are grouped into the following classes in accordance with IMO International Maritime Dangerous Goods Code (IMDG Code) and International Maritime Solid Bulk Cargoes (IMSBC) Code:

(1) Dangerous goods in packaged form

Class 1 Explosives, except goods in division 1.4, compatibility group S of IMDG Code;

Class 2.1 All flammable gases, compressed, liquefied or dissolved under pressure;

Class 2.3 All toxic gases having a subsidiary risk class 2.1;

Class 3 All flammable liquids having a flashpoint below 23℃ (closed-cup test);

Class 4.3 Liquids having a flashpoint below 23℃, which in contact with water, emit flammable gases;

Class 6.1 All toxic substances having a flashpoint below 23℃ (closed-cup test);

Class 8 All corrosive liquids having a flashpoint below 23℃ (closed-cup test);

Class 9 Miscellaneous dangerous substances emitting flammable gases.

(2) Solid dangerous goods in bulk

Class 4.1 Flammable solids;

Class 4.2 Substances liable to spontaneous combustion;

Class 4.3 Substances, which in contact with water, emit flammable gases;

Class 5.1 Oxidizing substances;

Class 9 Miscellaneous dangerous substances, that is, any other substance which experience has shown, or may show, to be of such a dangerous character that the provisions of this Section apply to it;

MHB Materials which may possess chemical hazards when transported in bulk other than materials classified as dangerous goods in the IMDG Code.

2.18.1.3 Possible hazardous areas for carrying the dangerous goods specified in this Section comprise the following:

(1) Zones and spaces, in which an explosive atmosphere① is likely to occur in normal operation, are defined as hazardous areas.

(2) Zones and spaces, in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only, are defined as extended hazardous areas.

2.18.1.4 Electrical equipment is to be installed in hazardous areas only when it is essential for the safety and operation of the ship. The explosion protection of the installed and operated electrical equipment is to be suitable for the characteristics of the dangerous goods.

2.18.2 Carriage of explosives class 1 in packaged form as specified in 2.18.1.2 (1) (except goods in division 1.4, compatibility group S)

2.18.2.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces, and closed or open ro-ro cargo spaces;

(2) permanently fixed containers (e.g. magazines).

2.18.2.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.2.2 are permitted in the hazardous areas specified in 2.18.2.1 of this Section.

Permitted Electrical Equipment **Table 2.18.2.2**

Environment	Electrical equipment			
	Type	Explosion group	Temperature class or maximum surface temperature	Degree of protection
Explosive dust	General electrical equipment		100℃	IP65
Explosive gas	Intrinsically safe Ex "i"	IIA	T5	
	Flameproof Ex "d"	IIA		

① An explosive atmosphere may exist due to gas and/or dust.

Environment	Electrical equipment			
	Type	Explosion group	Temperature class or maximum surface temperature	Degree of protection
	Increased safety Ex “e” (only for lighting)	II		
Explosive gas and dust	Intrinsically safe Ex “i”	IIA	T5	IP65
	Flameproof enclosure Ex “d”	IIA		
	Increased safety Ex “e” (only for lighting)	II		

2.18.3 Carriage of solid dangerous goods in bulk, including classes 4.1, 4.2, 5.1, 9 and MHB creating explosive dust atmosphere

2.18.3.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) or (2) above, without appropriate measures to prevent flammable dust from entering.

2.18.3.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required as follows are permitted in the hazardous areas specified in 2.18.3.1 of this Section (unless otherwise specified in 2.18.5):

(1) general electrical equipment

— degree of protection IP55;

— maximum surface temperature 200℃; or

(2) certified explosion-proof electrical equipment

— degree of protection IP55;

— temperature class T3.

2.18.3.3 Where dangerous goods are to be carried which require a lower surface temperature than that given in 2.18.3.2 of this Section, the relevant requirements are to be complied with (see also 2.18.7).

2.18.3.4 Where ammonium nitrate (UN1942) and ammonium nitrate fertilizer (UN2067) of class 5.1, ammonium nitrate fertilizer (UN2071) of class 9, ammonium nitrate-based fertilizer and ammonium nitrate-based fertilizer MHB are to be carried, all electrical equipment, other than that of certified safe type, in hazardous areas are to be electrically disconnected from the power source in accordance with the requirements of 2.18.8.1.

2.18.4 Carriage of flammable liquids having a flashpoint below 23 ℃ (classes 3, 6.1 and 8), flammable gas in packaged form (class 2.1), miscellaneous dangerous substances emitting flammable gases in packaged form (class 9) and substances emitting flammable gases in contact with water (solid class 4.3 and MHB generating flammable gases in contact with water)

2.18.4.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces and closed ro-ro cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) areas on weather deck, or semi-enclosed spaces on weather deck, within 1.5 m of any exhaust ventilation outlet of a hazardous area;

(4) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) and (2) above, and without appropriate measures to prevent flammable gas from entering.

2.18.4.2 The following zones or spaces are extended hazardous areas:

(1) spaces which are separated by self-closing gastight doors (watertight doors may be regarded as gastight) from the hazardous areas as mentioned in 2.18.4.1(1) and (2), and have natural ventilation;

(2) inside the air lock (if any) adjoining the hazardous areas as mentioned in 2.18.4.1;

(3) open or semi-enclosed spaces within 1.5 m of the hazardous areas as specified in 2.18.4.1(3).

2.18.4.3 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.4.3 are permitted in the hazardous areas specified in 2.18.4.1 and 2.18.4.2 of this Section (unless otherwise specified in 2.18.5).

Permitted Electrical Equipment **Table 2.18.4.3**

Type of hazardous areas	Electrical equipment		
	Type	Explosion group	Temperature class or maximum surface temperature
Hazardous areas	Intrinsically safe Ex “i”	IIC	T4
	Flameproof Ex “d”	IIC	
	Pressurized enclosure Ex “p”	II	
	Encapsulated Ex “m”	II	

Type of hazardous areas	Electrical equipment		
	Type	Explosion group	Temperature class or maximum surface temperature
Extended hazardous areas	Electrical equipment permitted in the above hazardous areas	IIC or II	T4
	Non-sparking Ex "n"	II	
	Appliances which do not generate sparks or arcs during normal operation		135℃

2.18.4.4 If cargoes to be carried do not include hydrogen gases, hydrogen mixtures or bulk cargo which may produce hydrogen under certain conditions, the explosion group required above may be IIB.

2.18.5 Carriage of solid dangerous goods in bulk and MHB only

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB are to be carried, electrical equipment of certified safe type installed in hazardous areas are to be in compliance with the minimum requirements of Table 2.18.5.1.

Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)

Table 2.18.5.1

Dangerous goods	IMO class	Dominant risk①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium ferrosilicon powder UN1395	4.3	H_2	—	IIC	T2
Aluminium silicon powder uncoated UN1398	4.3	H_2	—	IIC	T2
Aluminium smelting by-products or Aluminium remelting by-products UN3170	4.3	H2	—	IIC	T2
Aluminium smelting/remelting by-products, processed	MHB(WF and/or WT and/or CR)	H2	—	IIC	T1
Ammonium nitrate UN1942	5.1	—	—	—	T4
Ammonium nitrate-based fertilizer UN2067	5.1	—	—	—	T4
Ammonium nitrate-based fertilizer UN2071	9	—	—	—	T4
Ammonium nitrate-based fertilizer	—	—	—	—	T4
Ammonium nitrate-based fertilizer MHB	MHB(OH)	—	—	—	T4
Brown coal briquettes	MHB (CB and/or SH)	Dust, methane	IP55	IIA	T4
Coal	MHB (CB and/or SH and/or WF and/or CR)	Dust, methane	IP55	IIA	T4
Direct reduced iron (A)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (B)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (C)	MHB (SH and/or WF)	H_2	—	IIC	T2
Ferrophosphorus (including briquettes)	MHB (WF and/or WT)	H_2	—	IIC	T1
Ferrosilicon, with at least 25% but less than 30% silicon, or 90% or more silicon (including briquettes)	MHB (WF and/or WT)	H_2	—	IIC	T1
Ferrosilicon UN1408, with	4.3	H_2	—	IIC	T1

Dangerous goods	IMO class	Dominant risk①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
30% or more but less than 90% silicon(including briquettes)					
Iron oxide, spent or sponge iron, spent UN1376	4.2	Dust	IP55	IIA	T2
Seed cake, containing vegetable oil UN1386	4.2	Hexane	—	IIA	T3
Seed cake UN2217	4.2	Hexane	—	IIA	T3
Seed cakes and other residues of processed oily vegetables	MHB (SH)	Dust	IP55	IIA	T3
Silicomanganese (low-carbon)	MHB(WF and/or WT and/or TX)	H_2	—	IIC	T1
Solidified fuels recycled from paper and plastics	MHB (SH)	Combustible	IP55	—	T3
Sugarcane biomass pellets	MHB(CB and/or WF and/or WT and/or OH)	Combustible, dust	IP55	IIA	T3
Sulphur UN1350 (crushed lump and coarse grained)	4.1	Combustible, dust	IP55	—	T4
Zinc Ashes UN1435	4.3	H_2	—	IIC	T2
Wood torrefied	MHB(CB and/or SH and/or CR)	Combustible, dust	IP55	—	T3
Wood pellets, containing additives and/or binders	MHB(WF)	Dust	IP55	—	T3
Wood pellets, not containing any additives and/or binders	MHB(OH)	Dust	IP55	—	T3

Note: ① The term "risk" relates only to the risk of explosion due to dangerous goods and electrical appliances.

2.18.6 Pressurized protection and air locks

2.18.6.1 Spaces having openings into adjacent hazardous spaces or areas (such as the hazardous areas specified in 2.18.4.1(4) of this Section) may be regarded as non-hazardous spaces provided they are pressurized as indicated in the acceptable standards①.

2.18.6.2 Where air locks are fitted adjacent to a hazardous area specified in 2.18.4.1, the external spaces adjacent to the air locks and fitted with natural ventilation may be regarded as non-hazardous spaces.

2.18.7 Special requirements

2.18.7.1 If no details of the characteristics of the prospected cargo are available, or if a ship is intended for the carriage of all the materials defined in 2.18.1.2, the electrical equipment permitted in hazardous areas are to be in compliance with the following requirements:

— degree of protection provided by enclosure IP65;
— maximum surface temperature 85°C;
— explosion group IIC;
— temperature class T6.

2.18.8 Installation of electrical system in hazardous areas

2.18.8.1 If the electrical equipment installed is not suitable for use in areas where a risk of explosion exists, the equipment is to be capable of being disconnected and protected against unauthorized

① See IEC publication 60092-506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk.

re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.
2.18.8.2 Cables are to be armoured or braided, or to be laid in metallic conduits.
2.18.8.3 Cable joints in cargo spaces are to be avoided where possible. Where joints are unavoidable, they are to be enclosed in explosion-proof metallic or high strength plastic junction boxes, or encapsulated crimp sleeve cable joints.
2.18.8.4 Cable penetrations of decks and bulkheads are to be sealed against the passage of inflammable gas or vapour.

2.18.9 Portable electrical appliances in hazardous areas

2.18.9.1 Portable electrical appliances, which must be used in hazardous areas for operation of the ship, are to be of a certified safe type suitable for such areas and except for intrinsically safe circuits, generally provided with their own power source.

2.18.10 Carriage of flammable liquids having a flashpoint below 23℃ in packaged form (classes 3, 6.1 and 8), aluminium smelting by-products or aluminium remelting by-products (UN 3170), aluminium smelting or remelting by-products processed (MHB), ferrosilicon (MHB) and ferrosilicon (UN 1408)

2.18.10.1 The bilge pipes with flanges, valves, pumps, etc., constitute a source of release and the enclosing spaces (e.g. pipe tunnels, bilge pump rooms, etc.) are to be classified as an extended hazardous area (comparable with Zone 2) unless these spaces are continuously mechanically ventilated with a capacity for at least six air changes per hour.
2.18.10.2 Except where the space is protected with redundant mechanical ventilation capable of starting automatically, equipment not certified for Zone 2 are to be automatically disconnected following loss of ventilation while essential systems such as bilge and ballast systems are to be certified for Zone 2.
2.18.10.3 Where redundant mechanical ventilation is employed, equipment and essential systems not certified for Zone 2 are to be interlocked so as to prevent inadvertent operation if the ventilation is not operational. Audible and visual alarms are to be provided at a manned station if failure occurs.

Section 19 DETECTION OF WATER INGRESS IN CARGO HOLDS

2.19.1 Application

2.19.1.1 This Section applies to all bulk carriers, single hold cargo ships other than bulk carriers and multiple hold cargo ships other than bulk carriers and tankers of 500 gross tonnage and upwards engaged on international voyages. Bulk carriers mentioned in this Section are bulk carriers as defined in SOLAS Chapter XII.

2.19.2 Water level detector system

2.19.2.1 Water level detectors installed in cargo holds, ballast tanks and dry spaces are to comply with the relevant requirements of acceptable standards① in addition to the provisions of this Section, and are to be subject to type approval.
2.19.2.2 All bulk carriers to which this Section is applicable are to be fitted with water level detectors and the following requirements are to be satisfied:
(1) Audible and visual alarms are to be given in each cargo hold, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2.0 m. On bulk carriers to which SOLAS regulation XII/9.2 applies, detectors with only the latter alarm need be installed. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold.
(2) In any ballast tank forward of the collision bulkhead required by SOLAS regulation II-1/12, an audible and visual alarm is to be given when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.
(3) In any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, an audible and visual alarm is to be given at a water level of 0.1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the

① See resolution MSC.188(79)/Rev.2 adopted by IMO − Performance standards for water level detectors on ships subject to SOLAS regulations II-1/25, II-1/25-1 and XII/12.

ship's maximum displacement volume.

2.19.2.3 Single hold cargo ships having a length of less than 80 m and a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck are to be fitted in such space or spaces with water level detectors, which are to give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0.3 m, and another when such level reaches not more than 15% of the mean depth of the cargo hold. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold. The water level detectors required by this paragraph need not be fitted in ships having watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck.

2.19.2.4 Multiple hold cargo ships other than bulk carriers and tankers are to be fitted with water level detectors in each cargo hold intended for dry cargoes. Water level detectors are not required for cargo holds located entirely above the freeboard deck. The following requirements are to be satisfied:

(1) Giving audible and visual alarms at the navigation bridge, one when the water level above the bottom of the cargo hold reaches a height of not less than 0.3 m, and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m. For cargo holds which are occasionally used for water ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold.

(2) As an alternative to the water level detector at a height of not less than 0.3 m as per (1) of this paragraph, a bilge level sensor serving the bilge pumping arrangements required by SOLAS regulation II-1/35-1 and installed in the cargo hold bilge wells or other suitable location is considered acceptable, subject to:

① the fitting of the bilge level sensor at a height of not less than 0.3 m at the aft end of the cargo hold;

② the bilge level sensor giving audible and visual alarm at the navigation bridge which is clearly distinctive from the alarm given by the other water level detector fitted in the cargo hold.

2.19.2.5 The audible and visual alarms specified in 2.19.2.2 to 2.19.2.4 are to be located on the navigation bridge.

2.19.2.6 Detection equipment is to be suitably corrosion resistant for all intended cargoes. Detection equipment includes the sensor and any filter and protection arrangements for the detector installed in cargo holds and other spaces.

Equipment which is to be used in refrigerated cargo spaces is to satisfy the requirements of a suitable industry standard covering the relevant service temperatures.

2.19.2.7 Detection equipment is to be electrical equipment of a certified safe type complying with the requirements of 1.3.3.1, Chapter 1 of this PART. The explosion groups and temperature classes are determined in accordance with carried cargoes. The part of the water level detector system which has circuitry in the cargo area is to be of an intrinsically safe type and explosion protection type as specified in acceptable standards[①]. Where a ship is designed only for the carriage of cargoes that cannot create a combustible or explosive atmosphere, then the requirement for electrical equipment of certified safe type may not be mandatory provided that this is specified in the operation manual of the water level detector system, the ship's cargo book and the certificate relating to the carriage of specially identified cargoes.

2.19.2.8 Where the characteristics of the dust and gas are unknown, the explosion group of electrical equipment used in dust and/or gas hazardous space is not to be lower than IIIC and/or IIC and the temperature class is to be T6.

2.19.2.9 The electrical power supply for the water level detector system is to comply with the following:

(1) It is to be supplied from two independent sources of electrical power:

① the main source of electrical power and the emergency source of electrical power; or

② the main source of electrical power, and a continuously charged dedicated accumulator battery of which the arrangement, location and endurance for power supply (18 h) are equivalent to those of the emergency source of electrical power. The battery may be an internal battery of the water level detector system;

(2) The changeover of supply from one source of electrical power to another need not be integrated into the water level detector system;

(3) Failure of any of the two electrical power supplies is to be indicated by an alarm.

2.19.2.10 The degree of protection provided by enclosures for electrical components installed in cargo holds, ballast tanks and dry spaces are to satisfy the requirements of IP 68.

2.19.2.11 Where the cargo hold is used as water ballast, sensors provided in the hold are to be suitable for the maximum pressure that might occur in the hold.

---

① See IEC publication 60079.

2.19.3 Installation requirements for water level detectors

2.19.3.1 The sensors are to be located in a protected position that is in communication with the specified part of the cargo hold (usually the aft part) such that the position of the sensor detects the level that is representative of the levels in the actual hold space. These sensors are to be located either as close to the centerline as practicable, or at both the port and starboard sides of the cargo hold.

The sensors are to be placed at a distance not exceeding 1 corrugation spacing or 1 bulkhead vertical stiffener spacing from the centerline, otherwise sensors are to be located at both the port and starboard sides of the cargo hold.

2.19.3.2 The sensors are to be located at the specified height. These heights are to be measured from the upper surface of the inner bottom. For bilge level sensors in 2.19.2.4(2) of this Section, if the bottom of the bilge well is below the upper surface of the inner bottom, the heights of those sensors are to be measured from the bottom of the bilge well.

2.19.3.3 When a lining or insulation is fitted, if the lining or insulation is not constructed to a watertight standard, then the height is to be measured from the upper surface of the inner bottom. If the lining or insulation is tested as watertight, then the heights may be measured from the upper surface of the lining/insulation.

2.19.3.4 The detector installation is not to inhibit the use of any sounding pipe or other water level gauging device for cargo holds or other spaces.

2.19.3.5 Detectors and equipment are to be installed where they are accessible for survey, maintenance and repair.

2.19.3.6 Any filter element fitted to detectors is to be capable of being cleaned before loading.

2.19.3.7 Electrical cables and any associated equipment installed in cargo holds are to be protected from damage by cargoes or mechanical handling equipment associated with bulk carrier operations, such as in tubes of robust construction or in similar protected locations.

2.19.3.8 Any change/modification to the ship’s structure, electrical systems or piping systems that involves cutting and/or welding are to be approved by ISC prior to commencement of work.

CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 This Chapter applies to class-related electrical equipment. The additional requirements for high voltage electrical installations are given in Section 14, Chapter 2 of this PART, and additional requirements for electrical propulsion machinery are given in Chapter 15, PART EIGHT of the Rules.

3.1.1.2 Class-related electrical equipment is to be provided with certificates corresponding to its type. The specific requirements for certificates are given in Chapter 3, PART ONE of the Rules.

Section 2 ROTATING MACHINES

3.2.1 General requirements

3.2.1.1 The characteristics of the prime movers of generators and their governors are to comply with the relevant requirements of Chapters 7, 8 and 9, PART THREE of the Rules.

3.2.1.2 For generating sets operating in parallel, the governing characteristics of the prime mover are to be such as to ensure the load sharing specified in 3.2.7.5 and 3.2.8.5 of this Section. Facilities are to be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

3.2.1.3 Shaft material for electrical propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by ISC.

3.2.1.4 Electrical machines are to be protected against ill effects of shaft current.

3.2.1.5 For non-closed-type bearings of electrical machines, consideration is to be to the fitting of grease cups or oil holes and corresponding oil drainage so as to ensure efficient lubrication.

3.2.2 Plans and documents

3.2.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Detailed drawings of main parts including assembly of stators, assembly of rotors, drawing of rotating shaft, assembly of slip rings or commutators, drawing of bedplate, and structural drawing of connection boxes;

(3) Technical specifications of the products;

(4) Front panel arrangement and system control flow diagram (applicable to electrical propulsion motors and their controls);

(5) Electrical schematic diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls);

(6) External wiring diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.2.2 The following plans and documents are to be submitted for information:

(1) Specifications of associated electrical appliances (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.3 Temperature rise

3.2.3.1 The limits of temperature rise of air-cooled machines based on an ambient air temperature of 45℃ are given in Table 3.2.3.1.

3.2.3.2 Where the ambient air temperature for motor operation is more than 45℃, the permissible temperature rise is to be reduced by an amount equal to the difference between the actual air ambient temperature and 45℃, based on the specified value given in Table 3.2.3.1.

Where the ambient air temperature for motor operation is less than 45℃, the permissible temperature rise is to be increased by a value equal to the difference between the actual ambient air temperature and 45℃, based on the specified value given in Table 3.2.3.1, and the increased value is not to be more than 15 K.

For motors fitted with water-cooled heat exchanger, the temperature of cooling water at the inlet of the heat exchanger may be regarded as the ambient air temperature for motor operation.

Limits of Temperature Rise (K) of Air-Cooled Machines **Table 3.2.3.1**

Thermal classification		B			F			H		
Method of measurement		Th	R	ETD	Th	R	ETD	Th	R	ETD
Item	Part of machine									
1a)	AC windings of machines having output of 5,000 kW (or kVA) or more	–	75	80	–	100	105	–	120	125
1b)	AC windings of machines having output above 200 kW (or kVA), but less than 5,000 kW (or kVA)	–	75	85	–	100	110	–	120	135
1c)	AC windings of machines having output of 200 kW (or kVA) or less, other than those of items 1d) or 1e)	–	75	–	–	100	–	–	120	–
1d)	AC windings of machines having rated output of less than 600 W (or VA)	–	80	–	–	105	–	–	125	–
1e)	AC windings and/or encapsulated windings of self-cooled machines without a fan (IC410)	–	80	–	–	105	–	–	125	–
2	Windings of armatures having commutators	65	75	–	80	100	–	100	120	–
3	Field windings of AC and DC machines other than those of item 4	65	75	–	80	100	–	100	120	–
4a)	Field windings of synchronous machines with cylindrical rotors having DC excitation windings embedded in slots, excluding synchronous induction motors	–	85	–	–	110	–	–	130	–
4b)	Stationary field windings of DC machines having more than one layer	65	75	85	80	100	110	100	120	135
4c)	Single-layer low-resistance field windings of AC and DC machines and compensating windings of DC machines having more than one layer	75	75	–	95	100	–	120	120	–
4d)	Single-layer windings of AC and DC machines with exposed bare or varnished metal surfaces and single-layer compensating windings of DC machines	85	85	–	105	110	–	130	130	–

Notes:
1) The temperature rise or the temperature of any part of machine is not to be detrimental to the insulation of that part or to any other part adjacent to it.
2) With application of the superposition test method to windings of machines in items 1c), 1d) and 1e) with insulation classes B and F, the limits of temperature rise given for the resistance method may be exceeded by 5 K.
3) Multi-layer windings are to comply with the requirements of item 4d) where the under layers are all in contact with the circulating primary coolant.
4) Th – thermometer, R – resistance, and ETD – embedded temperature detector.

3.2.3.3 Main and emergency generators, including their exciters, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air temperature for an unlimited period, without the limits of temperature rise in Table 3.2.3.1 being exceeded.
Other generators and motors are to be rated in accordance with the duty which they have to perform and when tested under rated load conditions, the temperature rise is not to exceed the values given in Table 3.2.3.1. For intermittent service S2 machines, the limits of temperature rise of windings may be 10 K above the values given in Table 3.2.3.1.

3.2.4 Sparking

3.2.4.1 Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.
3.2.4.2 Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

3.2.5 Overloads

3.2.5.1 Machines are to withstand, on test, the following overcurrents or excess torques without injury:
DC generators: 50% overcurrent for 15 s;
AC generators: 50% overcurrent for 2 min;
DC motors: 50% excess torque for 15 s;
Polyphase asynchronous motors: 60% excess torque for 15 s;
Polyphase salient synchronous motors: 50% excess torque for 15 s;
Polyphase non-salient synchronous motors: 35% excess torque for 15 s;
Polyphase synchronous motors of asynchronous construction (wound rotor): 35% excess torque for 15 s.

3.2.6 Short-circuits

3.2.6.1 Ship's service generators are to be capable of withstanding the mechanical and thermal effects of a short-circuit current for the duration of any time delay for discrimination purposes when tripping a protective device. AC generators and their excitation systems are to be capable of maintaining, under steady-state short-circuit conditions, a current of at least 3 times the full load rated current for a duration of 2 s or where precise data are available, for the duration of any time delay which may be provided by a tripping device.

3.2.6.2 For determining the discrimination settings in the distribution system where the generator is going to be used, the generator manufacturer is to provide documentation showing the transient behaviour of the short circuit current upon a sudden short-circuit occurring when excited, and running at nominal speed. The influence of the automatic voltage regulator is to be taken into account, and the setting parameters for the voltage regulator are to be noted together with the decrement curve. Such a decrement curve is to be available when the setting of the distribution system's short-circuit protection is calculated. The decrement curve need not be based on physical testing. The manufacturer's simulation model for the generator and the voltage regulator may be used where this has been validated through the previous type test on the same model.

3.2.7 DC generators

3.2.7.1 All DC generators other than charging generators are, in general, to be of compound-wound or shunt-wound with automatic voltage regulator, or stabilized shunt-wound (shunt-wound with few turns of series windings).

3.2.7.2 Manual voltage regulators are to be provided at the control panel to enable the voltage of each DC generator to be adjusted separately. For each DC generator, at any temperature within the working range and at any load between no load and full load, and when the voltage varies from 80% to 105% of the rated value, the accuracy of voltage adjustment is to be as follows:
(1) 0.5% of rated voltage for generators of rating exceeding 100 kW;
(2) 1.0% of rated voltage for generators of rating not exceeding 100 kW.
The circuit of manual voltage regulators is in general to be capable of being opened and means are to be provided to protect against over-voltage when the circuit is opened. Non-opened circuit is permitted only in such a case where the manual voltage regulator could adjust the no-load voltage to a value approaching to the remanence voltage.
The handwheel of manual voltage regulators is to be so arranged that when it is turned clockwise, the generator voltage will rise and vice versa.

3.2.7.3 Equalizer leads are to have a cross-sectional area appropriate to the system but in no case less than 50% of that of the negative lead from the generator to the switchboard.

3.2.7.4 For compound-wound generators rated at 50 kW and over, at full load operating temperature and with due regard being paid to governing characteristics of the prime mover, the voltage regulation characteristics are to be such that voltage variations are within 1% of the rated voltage for 20% of the rated load, that voltage variations are within 2.5% of the rated voltage for the full rated load and that the average of the ascending and descending curves of voltage regulation characteristics between 20% load and full load does not vary more than 3% from the rated voltage.

3.2.7.5 All DC generating sets arranged to run in parallel are to be stable in operation. When the combined load on the sets is varied between 20% and 100% of the combined ratings, the individual load on each machine is not to differ from the theoretical load (proportional to rating) by an amount greater than:
(1) ±12% of the rated full load of the largest machine; or
(2) ±25% of the rating of the smallest machine when the rating of the smallest machine is less than 50% of that of the largest one.
Such a load sharing is not to result in overloading the smaller set.

3.2.8 AC generators

3.2.8.1 Each AC generator, unless of the self-regulated type, is to be provided with separate automatic and manual voltage regulators at the generator control panel.
3.2.8.2 Each AC generator driven by the prime mover having governing characteristics complying with Chapter 7, 8 or 9, PART THREE of the Rules together with its excitation system is to be capable of maintaining the voltage under steady conditions within ±2.5% of the rated voltage from zero to full load at rated power factor. These limits may be increased to ±3.5% for emergency generators.
3.2.8.3 When the generator is driven at rated speed and a voltage close to its rated voltage on no-load, and is subjected to a sudden change of symmetrical load within the limits of 60% of the rated current with a power factor not exceeding 0.4 (lagging), the transient voltage is not to fall below 85% nor exceed 120% of the rated voltage. The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage in not more than 1.5 s. For emergency generators, these values may be increased to plus or minus 4% of the rated voltage in not more than 5 s, respectively.
3.2.8.4 For AC generators, the sinusoidal distortion of the voltage waveform under no-load conditions is not to exceed 5%, except for small (e.g. less than 24 kW) generators.
3.2.8.5 All AC generating sets arranged to run in parallel are to be stable in operation. In the range between 20% and 100% of the combined rated load of all generators, the load sharing is to be as follows:
(1) The active load on any individual generator is not to differ from the proportionate share of the total active load by more than the lesser of the following:
① ±15% of the rated active output of the largest generator; or
② ±25% of the rated active output of the individual generator.
Facilities are to be provided to adjust the governor of the prime mover sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.
(2) The reactive load on any individual generator is not to differ from the proportionate share of the total reactive load by more than the lesser of the following:
① ±10% of the rated reactive output of the largest generator;
② ±25% of the rated reactive output of the smallest generator.

3.2.9 Testing
3.2.9.1 All electrical machines are to be tested by the manufacturer according to IEC Publication 60092-301. Manufacturer's test records are to be provided for machines for essential services.
3.2.9.2 All machines of 50 kW and over, intended for essential services, are to be surveyed by ISC Surveyors during test and, if appropriate, during manufacturing. ISC and the manufacturer may agree on an alternative survey plan which makes Surveyor's attendance in accordance with the requirements above unnecessary.
3.2.9.3 Items for type and routine tests of the electrical machines are to be in compliance with Table 3.2.9.3. Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Items for Type and Routine Tests of Electric Machines **Table 3.2.9.3**

No	Tests	AC Generators		Motors	
		Type test①	Routine test②	Type test①	Routine test②
1	Examination of the technical documentation, as appropriate and visual inspection	×	×	×	×
2	Insulation resistance measurement	×	×	×	×
3	Winding resistance measurement	×	×	×	×
4	Verification of the voltage regulation system	×	×③		
5	Rated load test and temperature rise measurements	×		×	
6	Overload/overcurrent test	×	×④	×	×④
7	Verification of steady short circuit conditions⑤	×			
8	Overspeed test	×	×	×⑥	×⑥
9	Dielectric strength test	×	×	×	×
10	No-load test	×	×	×	×
11	Verification of degree of protection	×		×	
12	Verification of bearings	×	×	×	×

Notes: ① Type tests on prototype machine or tests on at least the first batch of machines.
② The report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result.
③ Only functional test of voltage regulator system.
④ Only applicable for machines of essential services rated above 100 kW.

⑤ Verification of steady short circuit condition applies to synchronous generators only.
⑥ Not applicable for squirrel cage motors.

3.2.9.4 The tests required in Table 3.2.9.3 are to be in accordance with the requirements in 3.2.9.5 to 3.2.9.15, in addition to complying with the relevant requirements of acceptable standards①.

3.2.9.5 Visual inspection

A visual examination is to be made of the machine to ensure, as far as is practicable, that it complies with submitted technical documentation.

3.2.9.6 Insulation resistance measurement

Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester (DC megameter) between:

(1) all current carrying parts connected together and earth;

(2) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Table 3.2.9.6. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

Minimum Test Voltage and Minimum Insulation Resistance Value Table 3.2.9.6

Related voltage U_n (V)	Minimum test voltage (V)	Minimum insulation resistance (MΩ)
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1{,}000$	500	1
$1{,}000 < U_n \leq 7{,}200$	1,000	$(U_n/1{,}000) + 1$
$7{,}200 < U_n \leq 15{,}000$	5,000	$(U_n / 1{,}000) + 1$

3.2.9.7 Winding resistance measurement

The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

3.2.9.8 Verification of voltage regulation system

Verification results are to meet the requirements in 3.2.8.2 and 3.2.8.3 of the Section. Subject to agreement of ISC, such voltage regulation during transient conditions may be calculated values based on the previous type test records, and need not be tested during factory testing of a generator, however the calculation report is to be submitted by the manufacturer to demonstrate that the requirements of 3.2.8.3 are met.

3.2.9.9 Rated load test and temperature rise measurements

The temperature rises are to be measured at the rated output, voltage, frequency and the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests. Temperature rise is to be measured after the test and the limits of temperature rise are those specified in Table 3.2.3.1.

3.2.9.10 Overload/over-current tests

Electrical machines are to be able to withstand the overload/over-current tests as required in 3.2.5.1 of this Section after the rated load test. The overload test can be replaced at routine test by the over-current test.

3.2.9.11 Verification of steady short-circuit conditions

Verification of AC synchronous generators and their excitation systems is to be in accordance with the requirements in 3.2.6.1, 3.2.6.2 of this Section.

3.2.9.12 Overspeed test

Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

3.2.9.13 Dielectric strength test

Machines are to withstand a dielectric test as specified in IEC Publication 60034-1. For high voltage machines an impulse test is to be carried out on the coils according to 2.14.3.3 of this PART.

3.2.9.14 No load test

Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor or if a generator it is to be driven by a suitable means and excited to give rated terminal voltage. During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

3.2.9.15 Verification of degree of protection

---

① Refer to IEC Publication 60092-301: Electrical installations in ships – Part 301: Equipment – Generators and motors and IEC Publication 60034-1: Rotating electrical machines – Part 1: Rating and performance, or other equivalent standards.

As specified in the standards acceptable to ISC①.

3.2.9.16 Verification of bearings

Upon completion of the above tests, machines which have sleeve bearings are to be opened to establish that the shaft is correctly seated in the bearing shells.

Section 3 SWITCHGEAR ASSEMBLIES

3.3.1 Plans and documents

3.3.1.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Front panel arrangement;

(3) Technical specifications of the products;

(4) Electrical schematic diagram.

3.3.1.2 The following plans and documents are to be submitted for information:

(1) Specifications of associated electrical appliances;

(2) Operation instructions for the products (which may be omitted if they are covered in other plans and documents for switchgear assemblies);

(3) External wiring diagram.

3.3.2 Design and construction of switchgear assemblies

3.3.2.1 The construction of main and emergency switchboards is to satisfy the following requirements:

(1) The top of switchboards is to have a degree of protection of IP22, and where the switchboard is installed in the control room complying with the requirements of 2.1.4.2 of this PART, a protection of IP21 at the top may be accepted. The sides of switchboards are to have at least a degree of protection of IP2X. For switchboards having a rated voltage in excess of 500 V, a protection of at least IP2X at the rear is to be provided.

(2) For switchboards having a voltage to earth or a working voltage above 50 V, exposed live parts are not to be installed on the front.

(3) Insulated handrails are to be provided at the front of all main and emergency switchboards. Where access to the rear of above-mentioned switchboards is necessary for operational or maintenance purposes, an insulated handrail is to be fitted on the rear. And horizontal insulated handrails are to be fitted on a fixed part of the switchboard.

(4) Provision is to be made at the cable entry to switchboards so that there is no water leakage into the switchboard along the cables.

(5) The main bus-bar is to be subdivided in accordance with the requirements in 2.1.1.1(5) of this PART.

(6) Where the total capacity of the main generating sets exceeds 100 kVA, a separate cubicle is to be provided for each generator, and the cubicles are to be separated from each other by partitions of steel or flame-retardant material.

(7) Terminals for systems having a rated voltage above 500 V are to be separated from terminals for lower voltages and are to be clearly marked.

3.3.2.2 Section and distribution boards are to be enclosed according to Table 1.3.2.2 of this PART. All enclosures are to be constructed of flame-retardant and non-hygroscopic material, and are to be of robust construction.

3.3.2.3 The arrangement of protection of electrical installations and the choice of protective devices are to comply with the relevant requirements of Section 5 of Chapter 2 of this PART.

3.3.2.4 All instruments, switchgear, pilot lamps, push buttons, operating handles or handwheels fitted on switchboards are to be provided with durable labels indicating their purposes and operating positions.

3.3.2.5 A durable label indicating the purpose of each circuit and the rating or appropriate setting of its overload protective device is to be provided at the location of the protective device. For fuses above 500 V where the fuse holders permit the insertion of fuses for lower rated voltages, special warning labels are to be placed, for example, “CAUTION: 660 V FUSES ONLY!”.

3.3.2.6 Devices for monitoring the insulation level to earth, which are in compliance with the requirements of 2.4.2.2 of this PART, are to be provided on the main and emergency switchboards.

3.3.2.7 Pilot lamps are to be provided at the generator control panels to indicate whether the generator circuit breakers are at the on or off position. Where a space heater is provided for the generator, a pilot lamp

---

① Refer to IEC Publication 60034-5 Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification, or other equivalent standards.

indicating the operation of the space heater is to be provided at the control panel.
3.3.2.8 Means are to be provided at the control panel of DC generators to enable the voltage to be regulated in accordance with the requirements of 3.2.7.2 of this PART.
3.3.2.9 For each AC generator arranged to operate in parallel, a remote control device is to be provided at the control panel to enable the speed of the prime mover to be adjusted within 10% of its rated value.
3.3.2.10 Means are to be provided at the control panel for magnetization of the DC generator.
3.3.2.11 Shore connection boxes of shore supply or other external sources are to be provided with the following:
(1) suitable terminals for connecting the flexible cables;
(2) an earth terminal for connecting the hull to the shore;
(3) switches with necessary protection complying with the requirements of 2.5.9.5 of this PART;
(4) a lamp or voltmeter to indicate the terminal voltage;
(5) means for checking the polarity (for direct current) or the phase sequence (for three-phase AC) of the incoming supply in relation to the ship's system;
(6) means to prevent the imposing of excessive mechanical forces on cable terminals;
(7) a nameplate giving full information on the system of supply, the rated voltage and frequency (for AC) of the ship's system.
3.3.2.12 The charging facilities of battery charging and discharging boards for the emergency or transitional source of electrical power are to comply with the requirements of 2.11.3 of this PART.
3.3.2.13 A disconnect switch and a indicator light for power supply are to be provided on battery charging and discharging boards for the emergency or transitional source of electrical power.

3.3.3 Bus-bars

3.3.3.1 Bus-bars are to be made of conducting cathode copper or copper-sheeted aluminium alloy. The maximum permissible temperature rise for bus-bars is 45 K.
3.3.3.2 Bus-bars and their supports are to be designed to withstand the mechanical stresses which will arise during short-circuits.
3.3.3.3 Bare main bus-bars in main and emergency switchboards (excluding the conductors between the main bus-bar and the supply side of outgoing units) are to have the minimum clearances and creepage distances as given in Table 3.3.3.3.

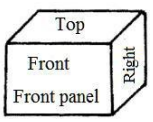
Minimum Clearances and Creepage Distances **Table 3.3.3.3**

Rated voltage (V)	Minimum clearance (mm)	Minimum creepage distance (mm)
$U_n \leq 250$	15	20
$250 < U_n \leq 690$	20	25
$U_n > 690$	25	35

Note: Values given in the Table apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

3.3.3.4 The current rating of equalizer bus-bars is not to be less than 50% of the rated full load current of the largest generator in the generating plant.
3.3.3.5 The cross sectional area of neutral bus-bar in AC three-phase four-wire systems are not to be less than 50% of that of the bus-bar in the corresponding phase.
3.3.3.6 The arrangement of bus-bars in the switchboard as per the phase sequence (DC) or the polarity (AC) is to be arranged in accordance with Table 3.3.3.6 (as viewed from the front of the assembly).

Arrangement per Phase Sequence or Polarity **Table 3.3.3.6**

Bus bar	Phase sequence or polarity	Position of bus bars			Sketch
		Vertically	Horizontally	Outgoing	
AC	1st phase	Top	Front	Left	As viewed from the front of switchboard assembly 
	2nd phase	Middle	Middle	Middle	
	3rd phase	Bottom	Back	Right	
DC	Positive pole	Top	Front	Left	
	Equalizer pole	Middle	Middle	Middle	
	Negative pole	Bottom	Back	Right	

Note: AC neutral bus-bars may be located at suitable positions.

3.3.4 Measuring instruments

3.3.4.1 The precision grade of instruments is to be selected according to the service of the instruments, but in no case is the precision grade to be inferior to 1.5.
3.3.4.2 The range and scale of the measuring instruments are to comply with the following requirements:
(1) The upper limit of the scale of every voltmeter is to be approximately 120% of the normal voltage of the circuit.
(2) The upper limit of the scale of every ammeter is to be approximately 130% of the normal rating of the circuit in which it is installed.
(3) The upper limit of the scale of every wattmeter is to be approximately 120% of the normal rating of the circuit in which it is installed. Ammeters for use with direct current generators operating in parallel and wattmeters for use with alternating current generators operating in parallel are to be capable of indicating 15% reverse current or power respectively.
(4) The frequency meter is to have a scale range of approximately ±10% of the rated frequency.
(5) Ammeters, voltmeters and wattmeters are to be clearly marked on the scale to indicate their rated values.
3.3.4.3 Generator control panels are to be provided at least with the measuring instruments as required in Table 3.3.4.3.
3.3.4.4 The secondary windings of potential and current transformers are to be effectively earthed.
3.3.4.5 At least the following meters are to be provided for battery charging and discharging boards for emergency or transitional sources of power:
(1) voltmeter to measure the charging voltage;
(2) ammeter to measure the charging current.

Measuring Instruments of Generator Control Panel **Table 3.3.4.3**

Generator	Operating condition	Type of instrument	Quantity
DC	Not in parallel	Ammeter	1 for each generator (connected to positive pole)
		Voltmeter	1 for each generator
	In parallel	Ammeter	1 for each generator (connected to positive pole)
		Voltmeter	2 (1 for measuring the bus-bar voltage, 1 for measuring the voltage of each generator)
AC	Not in parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	1 for each generator (to be capable of measuring the voltage in each phase or each line separately)
		Wattmeter	1 for each generator (excluding generators rated less than 50 kW (kVA))
		Frequency meter	1 for each generator
		Excitation ammeter	1 for each generator (to be fitted only when necessary)
	In parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	2 (1 for measuring the voltage in each phase or each line of the generator separately, 1 for measuring the bus-bar voltage)
		Wattmeter	1 for each generator
		Frequency meter	2 (1 for measuring the bus-bar voltage, 1 for measuring the frequency of each generator)
		Synchronous meter	1 for all generators
		Excitation ammeter	1 for each generator (to be fitted only when necessary)

3.3.5 Circuit breakers and switches

3.3.5.1 Circuit breakers are to be designed, manufactured and tested in accordance with IEC Publication 60947-2 or other recognized standards. Circuit breakers are to be of the trip-free type.
3.3.5.2 Circuit breakers and switches are to be so arranged that when in the OFF position, they cannot accidentally move to close the circuit.
3.3.5.3 The protective performance of circuit breakers for generators is to comply with the requirements of 2.5.6 of this PART. The overcurrent trip setting of these circuit breakers is to be adjustable, or if not adjustable, the set values are to be readily replaceable by different ones.
3.3.5.4 Where circuit breakers are operated by a power operating device, a hand operated mechanism is to be provided to operate the circuit breaker in case of failure of the electrical driven gear. For AC main switchboard of less than 1 kV in rated voltage, the generator circuit breaker is to be operated at the front of panels without opening the panel.
3.3.5.5 The fused circuit breakers are to be so constructed that single phasing does not occur in the event

of blowing of fuses and that the fuses can be replaced easily without the risk of accidental touch to their live parts.
3.3.5.6 Durable labels are to be fitted on circuit breakers to indicate their rated voltage, and the rated current and setting of their overcurrent trip devices, etc.

3.3.6 Fuses
3.3.6.1 Fuses are to be designed, manufactured and tested in accordance with IEC Publication 60269 or other recognized standards.
3.3.6.2 Fuses are to be of enclosed type and the construction is to be such that the enclosure is not broken or burnt and the adjacent insulation is not deteriorated by melted metal or emitted gases, when the fuse element has blown out.
3.3.6.3 Fuses are to be easily replaceable for their spare parts without the risk of getting electrical shock or burn on removing and replacing of fuses.
3.3.6.4 When fuses are operating for long periods at rated current, the temperature rise at the terminals is to be such that the maximum permissible operating temperature of the connected cable is not exceeded.
3.3.6.5 Fuses are to be durably marked to indicate their rated voltage, rated current and rated breaking capacity.

3.3.7 Testing
3.3.7.1 Switchboards are to be tested at the manufacturer in accordance with the provisions of 3.3.7.2 to 3.3.7.5 of this Section. However, the test required in 3.3.7.2 may be omitted for batch products of the same type.
3.3.7.2 Switchboards are to be subjected to temperature rise test at the specified load current.
3.3.7.3 Switchboards are to be subjected to functional testing for verifying the function of instruments and switchgear.
3.3.7.4 Switchboards are to be subject to high voltage test as required in Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.

Test Voltage **Table 3.3.7.4**

Rated voltage (V)	Test voltage a.c. r.m.s.(V)	Test voltage d.c.(V)
$U_n \leq 60$	1000	1415
$60 < U_n \leq 300$	1500	2120
$300 < U_n \leq 690$	1890	2670
$690 < U_n \leq 800$	2000	2830
$800 < U_n \leq 1{,}000$	2200	3110
$1{,}000 < U_n \leq 1{,}500$①	——	3820

Notes: ① For DC only.
② During testing all semi-conductor component parts are to be disconnected from the circuits to be tested and in the meantime, the measuring instruments, condensers, pilot lamps and other ancillary apparatus may also be disconnected.
③ The test voltage is to be applied between all current carrying parts and earthed enclosure, and between current carrying parts of different polarity or phase.

3.3.7.5 Insulation resistance measurement: Immediately after the high-voltage test, the insulation resistance between all current-carrying parts connected together and earth and between all current-carrying parts of different polarity or phase is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 4 CONTROL GEAR

3.4.1 General requirements
3.4.1.1 The operating wheels or handles of the control gear are to comply with the following requirements:
(1) The temperature is not to exceed 55℃ for those made of metal , and not to exceed 65℃ for those made of insulating material.
(2) They are to be provided with mechanically locking devices so that their operating positions will not be changed due to shock or vibration.

(3) They are to be provided with durable labels to indicate their purposes, positions and effect of movement.
3.4.1.2 The hand wheels of the control gear are to be arranged to rotate clockwise to "raise", "heave anchor", "haul in rope", and counterclockwise to "lower", "drop anchor", "pay out rope", if position "0" is the starting point.
The handles of control gear are to be arranged to move forward to "lower", "drop anchor", "pay out rope", and counterclockwise to "raise", "heave anchor", "haul in rope", if position "0" is the starting point.
3.4.1.3 The control gear is to be provided with protective devices complying with the relevant requirements of Section 5, Chapter 2 of this PART.
3.4.1.4 Suitable means are to be provided for the control push buttons against wrong action due to inadvertent touching.
3.4.1.5 Parallel field windings which allow an open circuit are to be provided with discharge circuits to protect against induced overvoltage.

3.4.2 Plans and documents
3.4.2.1 The following plans and documents are to be submitted for approval:
(1) General plan;
(2) Detailed drawings of main parts;
(3) Technical specifications of the products;
(4) Electrical schematic diagram.
3.4.2.2 The Operation Instructions for the Products is to be submitted for information.

3.4.3 Motor control gear
3.4.3.1 The motor control gear is to be provided with an indicating device to show that the motor is running.
3.4.3.2 The control gear of motors used for various services is also to comply with the relevant requirements of Section 6, Chapter 2 of this PART. The control gear of the steering gear is also to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.
3.4.3.3 The control gear of windlasses, warping winches, and cargo winches is to be provided with a device for emergency disconnection of the circuits.
3.4.3.4 Where windlass motors and warping winch motors have rating equal to or more than 10 kW, their control gears are to be provided with an ammeter to monitor the operating current of the motors, and this ammeter is to be properly illuminated or to be of fluorescent type.

3.4.4 Testing
3.4.4.1 Temperature rise test: Control gear is to be subjected to temperature rise test under normal working conditions. However, for the products of the same type and the same specification, only the first product is required to be tested.
3.4.4.2 Functional test: All control gears are to be subjected to functional testing.
3.4.4.3 High voltage test: The test is to be carried out according to Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.
3.4.4.4 Insulation resistance test: Immediately after the high voltage test, the insulation resistance is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 5 CABLES

3.5.1 General requirements
3.5.1.1 Cables are to comply with the requirements of this Section. Those not covered in this Section are to comply with the relevant requirements of acceptable standards①. Fire-resisting cables are to additionally comply with the relevant requirements for fire-resisting cables of acceptable standards②.

---

① Refer to IEC publications 60092-350, 60092-352, 60092-353, 60092-354, 60092-360, 60092-370 and 60092-376.
② Refer to:
IEC publication 60331-1 for testing electric cables of greater than 20 mm overall diameter;
IEC publication 60331-21 or 60331-2 for testing electric cable of up to 20 mm overall diameter;
IEC publication 60331-23 for testing electric data cables;
IEC publication 60331-25 for testing optical fibre cables.

3.5.1.2 Cables manufactured and tested to standards other than those specified in 3.5.1.1 will be accepted provided they are in accordance with an acceptable and relevant international or national standard and are of an equivalent or higher safety level than those listed in 3.5.1.1. However, cables such as flexible cable, fibre-optic cable, etc., used for special purposes may be accepted provided they are manufactured and tested in accordance with the relevant standards accepted by ISC.
3.5.1.3 Structural drawings and technical specifications of cables are to be submitted for approval.

3.5.2 Conductors

3.5.2.1 Conductors are to be of annealed copper with or without metal coating. The component copper wires are to be metal-coated and the wire surface is to appear smooth, uniform and bright when used for conductors having a thermosetting insulation, unless a separator between the conductor and the insulation is provided. The same applies to thermosetting insulation provided suitable type tests demonstrate that no harmful effects occur.
3.5.2.2 Conductor composition and stranding is to be according to IEC 60028 class 2 or class 5 and that adequate flexibility of the finished cable is assured. Cores of multi-core cables are to be readily identifiable.

3.5.3 Insulating materials

3.5.3.1 Permitted insulating materials and maximum rated conductor temperatures are to comply with the requirements of 2.12.2.2 of this PART. Insulating materials are to comply with the provisions of IEC60092-360.

3.5.4 Sheaths

3.5.4.1 The sheath is to be selected from one of those listed in IEC 60092-360 as specified in Table 3.5.4.1.

Sheath Materials **Table 3.5.4.1**

Type of materials		Remarks
Cross-linked material	Polychloroprene rubber	Suitable for use on insulating materials other than cross-linked polyethylene (XLPE); harmful smoke is released in case of fire.
	Chlorosulphonated polyethylene or chlorinated polyethylene rubber	
	Halogen-free rubber	——
Thermoplastic material	Polyvinyl chloride thermoplastic compound	Harmful smoke is released in case of fire.
	Halogen-free thermoplastic compound	——

3.5.4.2 Metal braid armour is to be made of galvanized steel, copper or copper alloy wires. The coverage density of the braid is to be such that the weight of the braid is at least 90% of the weight of a tube of the same metal, having an internal diameter equal to the internal diameter under the braid and a thickness equal to the nominal diameter of the wires forming the braid.
3.5.4.3 A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, chloroprene rubber tape or other suitable material. Textile materials are to be treated against moisture. The bedding is to be compatible with the operating temperature of the cable. It is to be possible to remove the bedding without damaging the underlying part.

3.5.5 Testing

3.5.5.1 Tests in accordance with the relevant acceptable standards① are to be made at the manufacturer prior to delivery.

Section 6 POWER AND LIGHTING TRANSFORMERS

3.6.1 General requirements

3.6.1.1 The requirements of this Section apply to single phase transformers rated at 1 kVA or more and 3-phase transformers rated at 5 kVA or more.

---

① Refer to IEC Publication 60092 or relevant standards.

3.6.1.2 All transformers, except those used for motor starting, are to be double wound or multi wound, with no electrical connection between primary and secondary windings.
3.6.1.3 In general, transformers are to be of dry air-cooled type. The use of liquid-filled transformers is to comply with the following requirements:
(1) Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Such transformers are to have a pressure release device with an alarm and there is to be a suitable means provided to contain any liquid which may leak from the transformer due to the operation of the release device or damage to the tank.
(2) Where forced liquid cooling is used, there is to be temperature monitoring of the cooling medium and transformer windings with an alarm being given when the temperature exceeds a preset limit, and provision is to be made for reducing the load to a level commensurate with the cooling available.
3.6.1.4 Transformers rated at 50 kVA and over are to be inspected by ISC Surveyors during testing and where necessary, during manufacturing.

3.6.2 Plans and documents

3.6.2.1 The following plans and documents are to be submitted for approval:
(1) General plan;
(2) Detailed drawings of main parts including coils, magnetic cores and connection boxes;
(3) Technical specifications of the products.
3.6.2.2 The following plans and documents are to be submitted for information:
(1) Operation instructions for the products;
(2) External wiring diagram.

3.6.3 Voltage regulation

3.6.3.1 The voltage drop of transformers supplying secondary distribution systems from no load to rated load at resistive load is not to exceed the following:
(1) 2.5% for single phase transformers rated more than 5 kVA or 3-phase transformers rated more than 15 kVA;
(2) 5% for single phase transformers rated up to 5 kVA or 3-phase transformers rated up to 15 kVA.

3.6.4 Temperature rise

3.6.4.1 The temperature rise of transformers at any part is not to exceed the values given in Table 3.6.4.1 during continuous operation at rated output, where the ambient air temperature is based on 45℃.

Limit of Temperature Rise **Table 3.6.4.1**

Part of transformer		Limit of temperature rise (K)	Method of measurement
Windings	Class A insulation	55	Resistance method
	Class E insulation	70	
	Class B insulation	75	
	Class F insulation	95	
	Class H insulation	120	
External surface of the magnetic core and structural components		Not to exceed the permissible temperature rise of the insulating material in contact	Thermometer or thermocouple

3.6.5 Short-circuits

3.6.5.1 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 s.

3.6.6 Tests

3.6.6.1 Performance tests (winding resistance measurement, voltage ratio measurement and check of phase displacement, short-circuit impedance and load loss measurement, no-load loss and no-load current measurement, etc.) are to to be carried out to all transformers at the manufacturer and in addition to the tests in 3.6.6.2 to 3.6.6.5 of this Section as a minimum, relevant tests are to be carried out in accordance with the requirements of IEC 60076 series publication and equivalent standards. However, the test required in 3.6.6.2 may only be carried out to the first product for batch products of the same type and specification.
3.6.6.2 Temperature rise test: Transformers are to be tested for temperature rise at rated output or in accordance with accepted standards[①]. The limits of temperature rise are not to exceed the values given in

① Refer to publications of IEC 60076 series or equivalent standards.

Table 3.6.4.1.

3.6.6.3 High voltage test[①②]: Transformers are to be subjected to high voltage test according to Table 3.6.6.3, applying a test voltage between primary and secondary windings and between windings and the earthed enclosure for 1 min without breakdown and flashover.

Voltage of High Voltage Test **Table 3.6.6.3**

Highest voltage (root-mean-square value) kV	Rated short duration power frequency withstand voltage (root-mean-square value) kV
≤ 1.1	3
3.6	10
7.2	20
12.0	28
17.5	38
24.0	50
36.0	70

3.6.6.4 Induced high voltage test: Transformers are to withstand an induced high voltage test with a voltage twice the rated voltage. The duration of the test is to be 1 min with a frequency less than or equal to twice the rated frequency. If the frequency is greater than twice the rated frequency, the duration of the test is to be obtained from the following formula with a minimum of 15 s:

$$t = \frac{60 \times 2 \times \text{rated frequency}}{\text{test frequency}} \quad \text{s}$$

For transformers subject to temperature rise test, the induced high voltage test is to be carried out immediately after the temperature rise test.

3.6.6.5 Insulation resistance test: The insulation resistance of each winding to earth is to be measured, with all other windings, magnetic core, frame and casing or enclosure connected together to earth, and recorded together with the temperature of the transformer at the test.

Section 7 STORAGE BATTERIES

3.7.1 General requirements

3.7.1.1 This Section is applicable to the permanently installed batteries.

3.7.2 Plans and documents

3.7.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Detailed drawings of main parts including enclosures and pole plates;

(3) Technical specifications of the products.

3.7.2.2 The Operation Instructions for the Products is to be submitted for information.

3.7.3 Type

3.7.3.1 Storage batteries used on board ships may be of lead-acid or nickel-alkaline type. Other types of batteries are not to be put on board ships without agreement of ISC.

3.7.4 Construction

3.7.4.1 All pole plates are to be of rigid construction, and are to be designed to reduce the shedding of active material to a minimum. The cells are to be so constructed as to prevent spilling of electrolyte due to an inclination of 40° from the normal, and to prevent emission of acid or alkaline spray.

3.7.4.2 The cells are to be grouped in crates or trays of rigid construction and suitable material and equipped with means to facilitate handling. The weight of the assembled batteries is preferably not to exceed 100 kg. This requirement does not apply to the cells the assembly of which in the above-mentioned crates or trays is impossible due to their weight.

3.7.4.3 Emergency accumulator batteries are to be so designed and arranged as to ensure that they will

---

① For transformers subject to temperature rise test, the high voltage test is to be carried out immediately after the temperature rise test.

② The high voltage test is in general not to be repeated, but if it is necessary, one additional test is permitted to be carried out with a test voltage equal to 75% of the voltage at the first test.

function at full rated power when the ship is upright or when inclined at any angle of list up to 22.5° or when inclined up to 10° either way in the fore or aft direction, or is in any combination of angles within those limits.

3.7.5 Nameplate

3.7.5.1 Each crate or tray is to be provided with a durable nameplate securely attached, indicating the manufacturer's name, type designation, voltage and the ampere-hour rating at a specific rate of discharge (preferably that corresponding to the duty for the specific application 5 h, 10 h or 20 h rating).

Section 8 POWER SEMICONDUCTOR CONVERTORS

3.8.1 General requirements

3.8.1.1 This Section is applicable to power semiconductor convertors using semiconductor rectifying elements such as diodes, reverse blocking triode thyristors etc., and does not apply to convertors for communication and the ancillary apparatus for instrumentation. The conversion may be from AC to DC, from DC to AC, from DC to DC and from AC to AC.

3.8.1.2 Unless otherwise specified by the manufacturer, the maximum permissible junction temperature of the rectifier cells is not to exceed the following values:

Selenium diodes: 70℃;
Silicon diodes: 150℃;
Silicon thyristor: 100℃ (up to 50 A);
125℃ (more than 50 A).

3.8.1.3 Semiconductor convertors are preferably to be of the dry air-cooled type.

3.8.1.4 Liquid-filled semiconductor convertors are preferably to be hermetically sealed. If provision is made for breathing, suitable desiccants are to be provided.

3.8.1.5 Transformers used in combination with semiconductor convertors are to be of two-winding transformers and are to comply with the relevant requirements of Section 6 of this Chapter.

3.8.1.6 Semiconductor convertors or semiconductor components are to be mounted in such a manner that they may be removed from a unit without dismantling the complete unit.

3.8.1.7 Mercury-based fungicides are not to be used in the vicinity of the selenium rectifiers.

3.8.2 Plans and documents

3.8.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;
(2) Electrical schematic diagram;
(3) Technical specifications of the products.

3.8.2.2 The following plans and documents are to be submitted for information:

(1) External wiring diagram;
(2) Specification list of associated electrical appliances;
(3) Operation instructions for the products.

3.8.3 Protection

3.8.3.1 Where forced cooling is provided, the circuit is to be so designed that the convertor cannot remain in operation unless effective cooling is maintained.

3.8.3.2 Semiconductor convertors are to be capable of withstanding the effects of transient over-voltage from the ship's network and the effects of DC voltage rise due to regenerated power.

3.8.3.3 Semiconductor convertors are to be protected against overload and short-circuit in accordance with the requirements of 2.5.14.1 of this PART.

3.8.3.4 For liquid-filled semiconductor convertors, consideration is to be given to the provision of an alarm for excessive liquid temperature and of pneumatic protection devices.

3.8.4 Testing

3.8.4.1 Semiconductor convertors are to be tested at the manufacturer in accordance with the requirements of 3.8.4.2 to 3.8.4.5 of this Section. However, the test required in 3.8.4.2 may be omitted for the products produced in series.

3.8.4.2 Semiconductor convertors are to be subjected to temperature rise test under normal working conditions.

3.8.4.3 Semiconductor convertors are to be subjected to functional test.

3.8.4.4 Semiconductor convertors are to withstand a high voltage test at the following testing voltage (with a minimum of 2,000 V):

$$U_p = 2 \times \frac{U_m}{\sqrt{2}} + 1000 \quad \text{V}$$

where: U_p — the effective value of testing voltage, in V;

U_m — the maximum no-load peak value between any pair of terminals of semiconductor convertors. If the voltage to earth is higher than the voltage between two terminals (e.g. the convertors are connected in series), the higher voltage, in V, is to be taken.

If $U_m/\sqrt{2}$ is less than 90 V, U_p is to be taken as 1,000 V.

This testing voltage is to be alternating at any frequency between 25 and 100 Hz and is to be applied between the live parts and any non-current carrying metal part which may be earthed for a period of 1 min without breakdown or flashover.

3.8.4.5 The insulation resistance between live parts of convertors or their accessories and earth is not to be less than 1 MΩ when tested with a DC 500 V megameter.

Section 9 UNINTERRUPTIBLE POWER SYSTEM

3.9.1 Application

3.9.1.1 The UPS① units, to which this Section applies, may provide an alternative power supply or transitional power supply, in lieu of independent accumulator batteries, to services as defined in 2.2.2.1(3) and 2.2.3.1(4) of Chapter 2 of this PART.

3.9.2 Plans and documents

3.9.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Electrical schematic diagram;

(3) Technical specifications of the products.

3.9.2.2 The following plans and documents are to be submitted for information:

(1) External wiring diagram;

(2) Specifications of associated electrical appliances;

(3) Operation instructions for the products.

3.9.3 Design and construction

3.9.3.1 UPS units are to be constructed in accordance with IEC 62040, or an acceptable a standard.

3.9.3.2 The operation of the UPS is not to depend upon external services.

3.9.3.3 The type of UPS unit employed, whether off-line, line interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

3.9.3.4 An external bypass is to be provided.

3.9.3.5 The UPS unit is to be monitored and audible and visual alarm is to be given in a normally attended location for:

(1) power supply failure (voltage and frequency) to the connected load;

(2) earth fault;

(3) operation of battery protective device;

(4) when the battery is being discharged; and

(5) when the bypass is in operation for on-line UPS units.

3.9.4 Performance

3.9.4.1 The output power is to be maintained for the duration required for the connected equipment as stated in 2.2.2.1(3) and 2.2.3.1(4) of Chapter 2 of this PART.

3.9.4.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity. The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in Chapter 2 of this PART.

3.9.4.3 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

---

① Refer to IEC publication 62040.

3.9.5 Testing and survey

3.9.5.1 UPS units of 50 kVA and over are to be surveyed by ISC Surveyors during manufacturing and testing.

3.9.5.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:

(1) Functionality, including operation of alarms;

(2) Temperature rise;

(3) Ventilation rate;

(4) Battery capacity.

3.9.5.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

Section 10 OTHER ELECTRICAL EQUIPMENT

3.10.1 Incandescent lighting

3.10.1.1 The voltage and load of tungsten filament lamps and lampholders are not to exceed the values specified in Table 3.10.1.1.

Voltage and Load of Tungsten Filament Lamps **Table 3.10.1.1**

Type of lampholders		Voltage (V)	Load
Bayonet cap	B22	250	200W/4A
	B15d	250	250W/4A
	B15s	55	15W/2A
Screw cap	E40	250	3,000W/16A
	E27	250	250W/4A
	E14	250	60W/2A

3.10.1.2 Lampholders are to be constructed of non-toxic, flame-retarding and non-hygroscopic material, and provided with means for locking the lamp in the holder.

3.10.1.3 The temperature rise of terminals for connection of supply cables is not to exceed 40 ℃. Insulation materials of internal parts are to have temperature class corresponding to the maximum temperature within the luminaires.

3.10.2 Tubular fluorescent lamp

3.10.2.1 The voltage and load of the fluorescent lamps and lampholders are not to exceed the values specified in Table 3.10.2.1.

Voltage and Load of Fluorescent Lamps **Table 3.10.2.1**

Type of lampholders	Voltage (V)	Load (W)
G13	250	115
G5	250	80

3.10.2.2 The construction of fluorescent lamp holders is to comply with the requirements of 3.10.1.2 and 3.10.1.3 of this Section.

3.10.3 Discharge lamps operating at voltages above 250 V

3.10.3.1 Discharge lamps must be securely fixed.

3.10.3.2 All independent ballasts, capacitors and other accessories mounted separately from the luminaires are to be enclosed in earthed metal casing.

3.10.3.3 Warning notices calling attention to "DANGER! HIGH VOLTAGE!" are to be provided in accordance with 2.7.1.3 of this PART.

3.10.4 Heating and cooking appliances

3.10.4.1 Heating elements are to be substantially guarded. The holes of the protective guard are to be sufficiently narrow to prevent foreign bodies from falling in.

3.10.4.2 Heating and cooking appliances are to be so constructed that the temperature of supply cable terminals will not exceed the maximum rated conductor temperature given in Table 2.12.2.2 of this PART.

3.10.4.3 Internal connection wires of heating and cooking appliances are to be continuously insulated with incombustible material. Connections between heating elements are not to be effected by soldering.

3.10.4.4 The insulation resistance of heating and cooking appliances in hot condition is not to be less than

0.5 MΩ.

3.10.4.5 Heating and cooking appliances are to be so constructed that the parts which must be hand-held in use cannot be heated to a temperature exceeding the values given in Table 3.10.4.5.

Maximum Temperature of Hand-Held Parts **Table 3.10.4.5**

Material of handles, grips and the like	Maximum temperature for normal hand-held operation (°C)	
	Long period	Short period
Metal	55	60
Porcelain, vitreous material, moulded material, rubber or wood	65	70

3.10.4.6 Heating and cooking appliances and their control gear fitted in galley spaces are to have a degree of protection of at least IP44. Their enclosures are to be corrosion-resistant and provided with one or more drainage holes.

3.10.4.7 Cooking appliances are to be so constructed that spilling or overflowing of liquid or food will not cause insulation failures or short-circuits.

3.10.4.8 Space heaters are to be so constructed, protected and installed that clothing, bedding or other combustible materials cannot come in contact with them in such a manner as to cause risk of fire. Furthermore, they are to be so constructed that combustible materials cannot be placed on the top of their enclosures.

3.10.4.9 Space heaters are to be equipped with means to interrupt the current when the temperature exceeds the permissible limit.

3.10.5 Accessories to luminaires

3.10.5.1 Accessories are to be so designed and constructed that the passages for the insulated conductors are of ample size and free from rough projections, sharp angles, and abrupt bends. All outlets for cables are to have well-rounded edges or be suitably bushed.

3.10.5.2 Accessories are to be so designed and insulated conductors so installed that stress cannot be applied by the conductors to any terminal to which the conductors may be connected.

3.10.5.3 Accessories are to be so designed and fixed that dust and moisture will not readily accumulate on live parts and their insulation.

3.10.5.4 Enclosures are to be made of metal or halogen-free flame-retardant insulating material.

3.10.5.5 When a socket has an earthing pin, the socket and plug are to have additional connections to earth the casing or frame of appliance. When inserting the plug, the earthing pin is to be connected before the live contact pins.

3.10.5.6 Socket outlets of current rating in excess of 16 A are to be interlocked with a switch such that the plug cannot be inserted or withdrawn when the switch is in the “on” position.

3.10.5.7 Socket outlets and plugs with protection degree of IP56 are to be provided with means to maintain the same degree of protection whether the plug is inserted or withdrawn.

3.10.6 LED luminaires for lighting purpose

3.10.6.1 LED luminaires described in this section are used for general lighting purpose only, excluding navigation lights, signal lights and colorful lights for decoration purpose.

3.10.6.2 LED luminaires are to comply with the provisions of IEC Publication 60598-1 Luminaires – Part 1: General requirements and tests and IEC 62722-2-1 Luminaire performance - Part 2-1: Particular requirements for LED luminaires.

CHAPTER 4 SUPPLEMENTARY REQUIREMENTS FOR CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

Section 1 CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

4.1.1 General requirements

4.1.1.1 The requirements of this Chapter apply to electrical installations on cargo ships of less than 500 gross tonnage, and may substitute for the related aforesaid requirements in this PART.

4.1.1.2 Except for tankers carrying dangerous liquid cargoes and ships carrying other dangerous goods, an earth indicator may be used instead of an alarm device for monitoring the insulation level to earth as required in 2.4.2.2 of this PART.

4.1.2 Distribution systems

4.1.2.1 In addition to the distribution systems as referred to in 2.4.1.1 of this PART, an AC three-phase four-wire insulated system may be used.

4.1.3 Main source of electrical power

4.1.3.1 The minimum comfortable conditions of habitability as required in 2.1.1.1(2) of this PART may not be complied with.

4.1.3.2 The requirements in 2.1.1.1(4) and (5) of this PART may not be complied with.

4.1.3.3 Distribution boards are not required to be positioned in accordance with 2.1.4.1 of this PART.

4.1.4 Reserve sources of electrical power

4.1.4.1 The emergency source of electrical power as required in Section 2, Chapter 2 of this PART may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;

② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of this PART;

③ capable of providing immediately power supply for any equipment as required in 4.4.4.1(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;

② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;

③ internal communication equipment required in emergency;

④ fire detection and fire alarm system (if any);

⑤ daylight signalling lamp in intermittent operation, the ship's whistle, the manually operated call points (if any) and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);

⑥ radio communications on board.

4.1.5 Control box for navigation lights

4.1.5.1 The control box of navigation lights may be supplied by the main switchboard and the reserve power source.

4.1.5.2 The alarms for failure required in 2.7.4.4 of this PART may not be satisfied.

4.1.6 Engineers' alarm system

4.1.6.1 Engineers' alarm system required in 2.8.4 of this PART may not be provided.

APPENDIX 1 SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS

1.1 General Provisions

1.1.1 General requirements

1.1.1.1 This Appendix applies to the calculation of three-phase short-circuit currents that occur on a marine AC electrical installation and short-circuit power factors. The value of a two-phase short-circuit current may be taken as 0.866 times the corresponding value of a three-phase short-circuit current.

1.1.1.2 The calculation methods are for use on unmeshed low and high voltage three-phase alternating current systems operating at 50 Hz or 60 Hz, and having their neutral point connected to the ship's hull through an impedance, or having their neutral point isolated from the ship's hull.

1.1.1.3 The calculating methods described produce sufficiently accurate results to calculate the short-circuit current during the first 100 ms of a fault condition. The results of calculation may be used for:

(1) checking short-circuit making and breaking capacity of the protection devices selected;

(2) checking electrodynamic stability and thermal equilibrium of bus-bars etc.;

(3) providing the basis for design and setting of electrical system protection;

(4) providing the basis for the selection, if necessary, of suitable devices capable of limiting short-circuit currents within the capacity of protective devices.

1.1.1.4 When calculating the maximum short-circuit current, the following are to be considered in the most severe condition, i.e. the condition corresponding to the fully loaded generating plant of ships or offshore installations:

(1) All short-circuit currents fed through generators which may be connected in parallel to the main bus-bar (including the generators transferring load in short time).

(2) All short-circuit currents fed through motors which may be put into service.

1.1.1.5 In general, the short-circuit current is to be calculated at:

(1) output of generators;

(2) main bus-bars;

(3) bus-bars of emergency switchboards, sub-switchboards and distribution boards;

(4) secondary side of power and lighting transformers.

Sometimes, feeder terminal short-circuit currents are additionally to be calculated for design and setting of electrical system protection.

1.1.1.6 The manufacturers are to provide the characteristic parameters of generators, motors, transformers and cables as needed by the calculations and ensure that the parameters are within sufficiently accurate.

1.1.2 Definitions

1.1.2.1 Short-circuit

The accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit, which are normally at different voltages.

1.1.2.2 Short-circuit current

An over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit without any change of the supply.

1.1.2.3 Prospective short-circuit current (with respect to a switching device)

The short-circuit current that would flow in the circuit if each pole of the device were replaced by a conductor of negligible impedance.

1.1.2.4 Symmetrical short-circuit current

The r.m.s. value of the AC symmetrical component of a prospective (available) short-circuit current, the DC component, if any, being neglected.

1.1.2.5 DC component of the short-circuit current

The component of current in the circuit immediately after it has been suddenly short-circuited, all components of fundamentals and harmonics being excluded.

1.1.2.6 Peak short-circuit current

The maximum possible instantaneous value of the prospective (available) short-circuit current.

1.1.2.7 Equivalent generator

In order to calculate short-circuit currents, individual generators and motors in service are combined to form an equivalent generator, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such generators and motors.

1.1.2.8 Equivalent motor

In order to simplify the calculation of short-circuit currents, individual motors in service, other than large

motors, are combined to form an equivalent motor, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such motors.

1.1.2.9 Large motor

Any motor rated more than 100 kW or 25% of the rated power of the maximum generator in the system.

1.1.3 Symbols, Subscripts and superscripts

1.1.3.1 General requirements

(1) The symbols, subscripts and superscripts specified in 1.1.3.2 and 1.1.3.3 below are used and uniform units provided in this Appendix.

(2) In case of impedance, reactance, resistance and voltage drops, capital letters denote absolute values and lowercase letters denote relative values (per unit or per cent).

(3) For time-dependent values (current, voltage), capital letters denote r.m.s. values and lowercase letters denote momentary (instantaneous) values.

1.1.3.2 Symbols

(1) Voltage symbols are given in Table 1.1.3.2(1).

Voltage Symbols **Table 1.1.3.2(1)**

Symbol	Name	Unit
E''_{q0}	Subtransient q-axis voltage of a generator	V
E'_{q0}	Transient q-axis voltage of a generator	V
E''_M	Subtransient voltage of a motor	V
U_r	Rated voltage (line to line)	V
U_{rM}	Rated voltage of a motor	V
U_{rT2}	Rated line voltage at the secondary side of a transformer	V
u_K	Rated short circuit voltage of a transformer in %.	%
u_R	Rated ohmic voltage of a transformer in %	%
u_x	Rated ohmic voltage of a transformer in %	%

(2) Current symbols are given in Table 1.1.3.2(2).

Current Symbols **Table 1.1.3.2(2)**

Symbol	Name	Unit
I''_{Kd}, I'_{Kd}	Subtransient and transient short-circuit current of a synchronous generator (r.m.s.)	kA
I''_*, I'_*	Subtransient and transient short-circuit current of an equivalent generator (r.m.s.)	kA
I_*	Current of an equivalent generator (r.m.s.)	kA
I''_M, I''_{M*}	Subtransient short-circuit current of a asynchronous motor and an equivalent motor (r.m.s.)	kA
I_{ac}	Symmetrical short-circuit current at the fault point (r.m.s.)	kA
I_{acG}	Symmetrical short-circuit current of a synchronous generator (r.m.s.)	kA
I_{acM}	Symmetrical short-circuit current of a asynchronous motor (r.m.s)	kA
i_{dc}	DC component of the short-circuit current at the fault point	kA
i_{dcG}	DC component of the short-circuit current of a synchronous generator	kA
i_{dcM}	DC component of the short-circuit current of an asynchronous motor	kA
i_K	Upper envelope of the short-circuit current	kA
I_{K*}	Steady state short-circuit current of an equivalent generator (r.m.s.)	kA
I_{Kd}	Steady state short-circuit current of a synchronous machine (r.m.s.)	kA
i_M	Upper envelope of the short-circuit current of a asynchronous motor	kA
i_{pG}	Peak value of the short-circuit current of a synchronous machine	kA
i_{pM}	Peak value of the short-circuit current of an asynchronous motor	kA
i_p	Peak value of the short-circuit current at the fault point	kA
I_r	Rated current (r.m.s.)	kA
I_{ac2}	Symmetrical short-circuit current at the secondary side of a transformer (r.m.s.)	kA
i_{K2}	Upper envelope of the short-circuit current at the secondary side of a transformer	kA
i_{p2}	Peak value of the short-circuit current at the secondary side of a transformer	kA
I_{CR}	Rated short-circuit breaking capacity of a circuit breaker, as given	kA

Symbol	Name	Unit
I_{Cr}	Rated short-circuit breaking capacity of a circuit breaker, as converted	kA

(3) Symbols of reactance, resistance and impedance are given in Table 1.1.3.2(3).

Symbols of Reactance, Resistance and Impedance **Table 1.1.3.2(3)**

Symbol	Name	Unit
R	Resistance	mΩ
r	Cable resistance per unit length	mΩ/m
R_*	Stator resistance of an equivalent generator	mΩ
R_a	Stator resistance of a synchronous generator	mΩ
R_M	Resistance of an asynchronous motor	mΩ
R_R	Rotor resistance of an asynchronous motor as converted to the stator side	mΩ
R_{R*}	Rotor resistance of an equivalent asynchronous motor as converted to the stator side	mΩ
R_S	Stator resistance of an asynchronous motor	mΩ
R_{S*}	Stator resistance of an equivalent asynchronous motor	mΩ
R_T	Resistance of a transformer	mΩ
X	Reactance	mΩ
x	Cable reactance per unit length	mΩ/m
X''_*, X'_*	Subtransient and transient reactance of an equivalent generator	mΩ
X''_d, X'_d	Subtransient and transient reactance of a synchronous generator in the d-axis	mΩ
X''_M	Subtransient reactance of an asynchronous motor	mΩ
X''_{M*}	Subtransient reactance of an equivalent asynchronous motor	mΩ
X_R	Rotor reactance of an asynchronous motor as converted to the stator side	mΩ
X_S	Stator reactance of an asynchronous motor	mΩ
X_d	Reactance of a synchronous generator in the d-axis	mΩ
X_T	Reactance of a transformer	mΩ
Z	Impedance	mΩ
Z_*	Equivalent impedance	mΩ
Z''_d, Z'_d	Subtransient and transient impedance of a synchronous generator	mΩ
Z''_*, Z'_*	Subtransient and transient impedance of an equivalent generator (including circuit impedance)	mΩ
Z''_M	Subtransient impedance of an asynchronous motor	mΩ
Z''_{M*}	Subtransient impedance of an equivalent asynchronous motor	mΩ
Z_T	Impedance of a transformer	mΩ
R_{e1}	Primary cable resistance of a transformer	mΩ
R_{e2}	Cable resistance at the secondary side of a transformer as converted to the primary side	mΩ
X_{e1}	Primary cable reactance of a transformer	mΩ
X_{e2}	Cable reactance at the secondary side of a transformer as converted to the primary side	mΩ

(4) Symbols of time and time constants are given in Table 1.1.3.2(4).

Symbols of time and time constants **Table 1.1.3.2(4)**

Symbol	Name	Unit
t	Time duration from the beginning of a short circuit	ms
t_x	Defined time duration from the beginning of a short circuit	ms
T''_d, T'_d	Subtransient and transient time constant of a synchronous generator in the d-axis	ms
T''_{d*}, T'_{d*}	Subtransient and transient time constant of an equivalent generator in the d-axis	ms
T''_e, T'_e	Subtransient and transient time constant of a synchronous generator including non-active components	ms
T''_M, T''_{M*}	Subtransient time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T''_{Me}	Subtransient time constant of an asynchronous motor including the connecting cables	ms
T_{dc}, T_{dc*}	DC time constant of a synchronous generator and an equivalent generator	ms

Symbol	Name	Unit
T_{dce}	DC time constant of a synchronous generator including non-active components	ms
T_{dcM}, T_{dcM*}	DC time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T_{dcMe}	DC time constant of an asynchronous motor including the connecting cables	ms

(5) Power symbols are given in Table 1.1.3.2(5).

Power Symbols **Table 1.1.3.2(5)**

Symbol	Name	Unit
S_{rG}	Rated apparent power of a synchronous generator	kVA
P_{rG}	Rated power of a synchronous generator	kW
P_{rM}	Rated output power of an asynchronous motor	kW
P_{rM*}	Rated output power of an equivalent asynchronous motor	kW
S_{rT}	Rated apparent power of a transformer	kVA
P_K	Short circuit losses of a transformer	kW

(6) Other symbols are given in Table 1.1.3.2(6).

Other Symbols **Table 1.1.3.2(6)**

Symbol	Name	Unit
$\cos\varphi_K$	Power factor of a short circuit	
$\cos\varphi_r$	Rated power factor of a generator	
$\cos\varphi_M$	Rated power factor of an asynchronous motor	
η_M	Efficiency of an asynchronous motor	
a	Number of parallel cables	
A_i	Fault point at the power end of a generator breaker	
B_i	Fault point adjacent to the main bus-bar	
C_i	Fault point in the feeder circuit of primary distribution system outside the main bus-bar	
D_i	Fault point at the secondary side of a transformer	
e	Radix of exponential	
f	Frequency	Hz
l	Cable length	m
n	Coefficient of peak value	
S	Sectional area of cable	mm^2
T	Period	ms
CB	Circuit breaker	
FU	Fuse	

1.1.3.3 Subscripts and superscripts

(1) Symbols of subscripts are given in Table 1.1.3.3(1).

Symbols of Subscripts **Table 1.1.3.3(1)**

Symbol	Meaning
*	Equivalent generator and equivalent asynchronous motor
0	Prefault condition
a	**ARMATURE**
ac	**ALTERNATING CURRENT**
d	**DIRECT AXIS**
dc	Direct current
e	Value including non-active components (external)
E, I, U	phasor of E,I and U
G	Synchronous generator
i	Number of generators
j	Number of motors
K	Short circuit
M	Asynchronous motor or group of asynchronous motors
q	Quadrature-axis
R	Rotor of an asynchronous motor

Symbol	Meaning
S	Stator of an asynchronous motor
T	Transformer
Z	Complex impedance

(2) Symbols of superscripts are given in Table 1.1.3.3(2).

Symbols of Superscripts **Table 1.1.3.3(2)**

Symbol	Meaning
”	Subtransient value
,	Transient value

1.2 Calculation of Short-circuit Currents

1.2.1 Basic assumptions

1.2.1.1 The formulae described herein, calculate the upper envelope of the maximum value of the time dependent short-circuit current (see Figure 1.2.2.2). The envelope is calculated using particular machine characteristic parameters obtainable from equipment manufacturers using recognized testing methods, and applying the following assumptions:

(1) all system capacitances are neglected;

(2) at the start of the short circuit, the instantaneous value of voltage in one phase at the fault point is zero;

(3) during the short circuit, there is no change in the short-circuit current path;

(4) the short-circuit arc impedance is neglected. The impedance of the bus-bar, potential transformer (PT) and the contact resistance of the connecting points between the conductors are also neglected;

(5) transformers are set at the main tap position;

(6) the short circuit occurs simultaneously in all three phases;

(7) in the prefault condition, the generator is operated at its rated values of load;

(8) for generators connected in parallel, all generators share their active and reactive load proportionally at the start of and during the short circuit;

(9) during each discrete time interval, all circuit components react linearly.

With the above assumptions, the calculation results are considered to be acceptable for the engineering objectives.

1.2.2 Calculation of the short-circuit current fed through a synchronous machine

1.2.2.1 General

(1) The synchronous machines used on marine/offshore electrical installations comprise synchronous generators, motors and condensers. The short-circuit currents produced by these machines are fundamental to the calculation of the short-circuit current of an electrical system.

During the first few cycles of a short circuit, all synchronous machines respond in a similar way and accordingly the short-circuit current produced has the same basic characteristics.

(2) Equivalent electrical circuit

When the three-phase terminal short-circuit current of a synchronous generator occurs, the equivalent electrical circuit under subtransient and transient conditions are as shown in Figure 1.2.2.1.

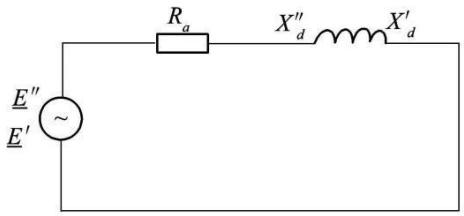
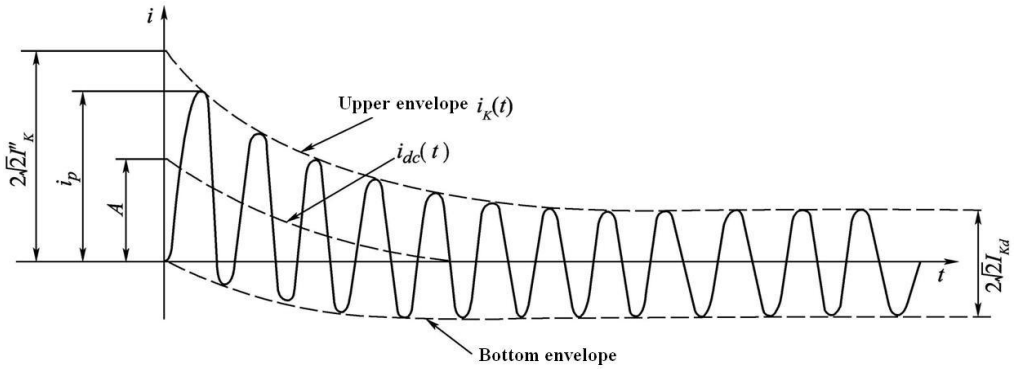


Figure 1.2.2.1 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of a Synchronous Generator

1.2.2.2 Three-phase short-circuit current

(1) The three-phase short-circuit current condition occurs when all three phase are simultaneously shorted together. The resulting current is a complex time-dependent function occurring in each phase. The time-dependent oscillogram of the typical three-phase terminal short-circuit current of a synchronous generator is shown in Figure 1.2.2.2. The current consists of a synchronous short-circuit current (AC components) and DC components.



I''_K – Initial symmetrical short-circuit current; i_p – Peak short-circuit current; I_{Kd} – Steady-state short-circuit current; i_{dc} – Decaying (aperiodic) component of short-circuit current; A – Initial value of the aperiodic component

Figure 1.2.2.2 Terminal Short-Circuit Current Time Function of a Typical Synchronous Generator on No-Load

1.2.2.3 Calculation of the shot-circuit current

(1) When calculating the short-circuit current, it is usual to consider only the highest values of the current, Figure 1.2.2.2 shows that the highest values vary as a function of time along the upper envelope of the complex time-dependent function. The current $i_K(t)$ defined by this upper envelope is calculated from formula (1):

$$i_K(t) = \sqrt{2} I_{ac}(t) + i_{dc}(t) \tag{1}$$

(2) The calculation of symmetrical short-circuit current $I_{ac}(t)$

$I_{ac}(t)$ may be calculated using the following formulae:

$$I_{ac}(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + (I'_{Kd} - I_{Kd}) \cdot e^{-t/T'_d} + I_{Kd} \tag{2}$$

$$I''_{Kd} = \frac{E''_{q0}}{Z''_d} = \frac{E''_{q0}}{\sqrt{R_a{}^2 + X''_d{}^2}} \tag{3}$$

$$I'_{Kd} = \frac{E'_{q0}}{Z'_d} = \frac{E'_{q0}}{\sqrt{R_a{}^2 + X'_d{}^2}} \tag{4}$$

$$E''_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a \cdot I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X''_d \cdot I_r\right)^2} \tag{5}$$

$$E'_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a \cdot I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X'_d \cdot I_r\right)^2} \tag{6}$$

(3) I_{Kd} is the steady-state short-circuit current and to be obtained from the manufacturer.

(4) The calculation of the DC component $i_{dc}(t)$

$i_{dc}(t)$ may be calculated from the following formula (7):

$$i_{dc}(t) = \sqrt{2}(I''_{Kd} - I_r \cdot \sin\varphi_r) \cdot e^{-t/T_{dc}} \tag{7}$$

(5) The calculation of the peak value i_p of the short-circuit current

The peak value of the short-circuit current occurs between time $t = 0$ and $t = T/2$ of the short-circuit condition. The exact time depends on the preload conditions, the generator impedance and time constants. In general, it is acceptable to calculate i_p at time $T/2$, i.e. at the first half cycle of the short-circuit condition, using formula (8):

$$i_p = \sqrt{2} I_{ac}\left(\frac{T}{2}\right) + i_{dc}\left(\frac{T}{2}\right) \tag{8}$$

1.2.3 Calculation of the short-circuit current fed through a asynchronous motor

1.2.3.1 General

(1) Quite a number of asynchronous motors are fitted on ships and offshore installations, which can be considered in two broad groups, i.e. large motors and small motors. The grouping depends upon both the system generator capacity and the actual motor rating.

(2) When a short circuit occurs on a system, all motors connected at instant of short circuit, contribute to the short-circuit current. In general large motors must be evaluated individually. Small motors may be grouped together and treated as an equivalent single source.

1.2.3.2 Equivalent electrical circuit

(1) Where the three-phase terminal short-circuit current of an asynchronous motor occurs, the equivalent electrical circuit is as shown in Figure 1.2.3.2.

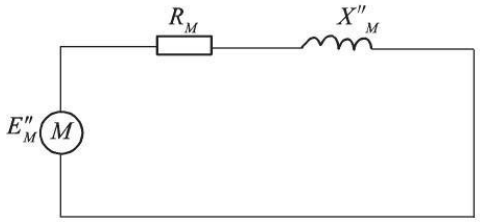


Figure 1.2.3.2 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of an Asynchronous Motor

1.2.3.3 Basic calculation of three-phase short-circuit currents

(1) The upper envelope $i_M(t)$ of the maximum values of the three-phase short-circuit current of an asynchronous motor may be obtained from the following formula:

$$i_M(t) = \sqrt{2} I_{acM}(t) + i_{dcM}(t) \tag{9}$$

(2) The calculation of the symmetrical short-circuit current $I_{acM}(t)$

$I_{acM}(t)$ may be obtained from formula (10):

$$I_{acM}(t) = I''_M \cdot e^{-t/T''_M} \tag{10}$$

If the preload condition is ignored, I''_M may be obtained from the formula (11):

$$I''_M = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{(R_R + R_S)^2 + (X_R + X_S)^2}} = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{R_M{}^2 + X''_M{}^2}} \tag{11}$$

(3) Where the of preload condition is ignored, the DC component $i_{dcM}(t)$ and the peak value i_{pM} of the short-circuit may be obtained from formulae (12) and (13) respectively:

$$i_{dcM}(t) = \sqrt{2} I''_M \cdot e^{-t/T_{dcM}} \tag{12}$$

$$i_{pM} = \sqrt{2} I_{acM}(\frac{T}{2}) + i_{dcM}(\frac{T}{2}) \tag{13}$$

1.2.3.4 Calculation of the short-circuit current of large motors

(1) For large motors defined in 1.1.2.9, the terminal short-circuit current is to be calculated using respectively the calculation methods given in 1.2.3.3.

(2) If insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$z''_M = 0.16$

$x''_M = 0.15$

$r_S = 0.034$

$r_R = 0.021$

② Time constants

At 50 Hz, $T''_M = 22.4$ ms, $T_{dcM} = 14.08$ ms

At 60 Hz, $T''_M = 18.67$ ms, $T_{dcM} = 11.73$ ms

1.2.3.5 Calculation of the short-circuit current of small motors

(1) Comparatively speaking, except large motors involved in 1.2.3.4(1), all other motors fitted on ships or offshore installations belong to small motors. The total motor group including their connecting cables may be considered as a single equivalent motor and if insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$z''_M = 0.2$

$x''_M = 0.188$

$r_S = 0.043$

$r_R = 0.027$

② Time constants

At 50 Hz, $T''_M = 22.4$ ms, $T_{dcM} = 14.08$ ms

At 60 Hz, $T''_M = 18.67$ ms, $T_{dcM} = 11.73$ ms

(2) The rated output of the equivalent motor may be calculated in accordance with the Electrical Load Calculations or may be taken as 60% of the total rated active output of actually running generators (excluding those transferring loads in short time) minus the sum of the rated outputs of individual large motors.

1.2.4 Effects of non-active component impedances on short-circuit currents

1.2.4.1 General

(1) In actual electrical systems, the cables, transformers and reactors connected in series with synchronous motors and asynchronous motors are to be also taken into account. Although these components do not feed the short-circuit current, they have a significant impact on the value of the short-circuit current. In general, the net effect is a lower value of short-circuit current which decays more slowly.

1.2.4.2 Effects on short-circuit current of generators

(1) Non-active component impedances R_e and X_e are taken into account by increasing the impedance of the active components, and in formulae (3) and (4) Z''_d and Z'_d are to be replaced by Z''_e and Z'_e where

$$Z''_e = \sqrt{(R_a + R_e)^2 + (X''_d + X_e)^2} \tag{14}$$

$$Z'_e = \sqrt{(R_a + R_e)^2 + (X'_d + X_e)^2} \tag{15}$$

For steady-state short-circuit currents accordingly:

$$Z_e = \sqrt{(R_a + R_e)^2 + (X_d + X_e)^2} \tag{16}$$

However, the effects of the cable impedance on steady-state short-circuit currents between the generator and the main switchboard near the main bus-bar may be ignored.

(2) Time constants T''_d, T'_d and T_{dc} are also changed and become T''_e, T'_e and T_{dce}

$$T''_e = \frac{[(R_a + R_e)^2 + (X''_d + X_e)^2] \cdot X'_d \cdot T''_d}{[(R_a + R_e)^2 + (X''_d + X_e)(X'_d + X_e)] \cdot X''_d} \tag{17}$$

$$T'_e = \frac{[(R_a + R_e)^2 + (X'_d + X_e)^2] \cdot X_d \cdot T'_d}{[(R_a + R_e)^2 + (X'_d + X_e)(X_d + X_e)] \cdot X'_d} \tag{18}$$

$$T_{dce} = \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a} \tag{19}$$

1.2.4.3 Effects on short-circuit current of motors

(1) The impedance is increased and in formula (11) R_M and X''_M are to be replaced by R_{Me} and X''_{Me} where

$$R_{Me} = R_R + R_S + R_e \tag{20}$$

$$X'_{Me} = X_R + X_S + X_e \tag{21}$$

(2) Time constant changes

The subtransient time constant:

$$T''_{Me} = \frac{1000 X''_{Me}}{2\pi f R_R} \tag{22}$$

The DC time constant:

$$T''_{dcMe} = \frac{1000 X''_{Me}}{2\pi f (R_s + R_e)} \tag{23}$$

1.2.5 Calculation of short-circuit currents at the main bus-bar

1.2.5.1 General

(1) Owing to neglecting the contact resistance between bus-bars, mutual inductors and conductors, the short circuits within the main bus-bar in the main switchboard are regarded as the short circuit at the main bus-bar.

1.2.5.2 Calculation of the short-circuit current

(1) With the assumption that a ship's electrical system is provided with *i* generators and *j* motors connected in parallel to the main bus-bar, the maximum short-circuit current at the main bus-bar is to be calculated as follows:

① First, the short-circuit current fed through each individual generator and motor is to be calculated in accordance with the requirements of 1.2.2, 1.2.3 and 1.2.4 of this Appendix.

② The maximum short-circuit current at the main bus-bar is to be the algebraic sum of short-circuit currents of individual generators and motors, i.e.:

$$I_{ac}(t) = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \tag{24}$$

$$i_{dc}(t) = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \tag{25}$$

$$i_K(t) = \sum_i i_{KG}(t)_i + \sum_j i_{KM}(t)_j \tag{26}$$

1.2.6 Calculation of the short-circuit current at the feeder circuit outside the main bus-bar

1.2.6.1 Application of the equivalent generator

(1) In order to calculate the short-circuit current at the feeder outside the main bus-bar, all generators and motors, which feed the short-circuit current to fault points, are to be combined to form an equivalent generator at the point of common connection (at the main bus-bar). The short-circuit current fed through the equivalent generator is equal to the sum of the short-circuit currents fed through individual generators and motors.

1.2.6.2 Determination of the characteristic parameters of an equivalent generator

(1) As mentioned above, the short-circuit current fed through the equivalent generator at the main bus-bar is correspondingly equal to the sum of the short-circuit currents fed through individual generators and motors, i.e.:

$$I_{ac}(t)_* = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \tag{27}$$

$$i_{dc}(t)_* = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \tag{28}$$

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej} \tag{29}$$

$$I'_* = \sum_i I'_{Kdei} \tag{30}$$

$$I_{K*} = \sum_i I_{Kdei} \tag{31}$$

(2) As in the case of a single generator, the time function $I_{ac}(t)_*$ of the symmetric short-circuit current of the equivalent generator is corresponding to formula (2) as follows:

$$I_{ac}(t)_* = (I''_* - I'_*) \cdot e^{-t/T''_{d*}} + (I'_* - I_{K*}) \cdot e^{-t/T'_{d*}} + I_{K*} \tag{32}$$

Assuming $M_* = I''_* - I'_*$

$N_* = I'_* - I_{K*}$

formula (32) may be rewritten as:

$$I_{ac}(t)_* = M_* \cdot e^{-t/T''_{d*}} + N_* \cdot e^{-t/T'_{d*}} + I_{K*} \tag{33}$$

(3) Determination of equivalent generator subtransient time constant T''_{d*}

Ignoring the transient decay of the short circuit of the generator, the time-dependent function $K''(t)$ of the symmetric short-circuit current for each generator may be expressed as follows:

$$K''(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + I'_{Kd} \tag{34}$$

For the equivalent generator accordingly:

$$K''(t)_* = M_* \cdot e^{-t/T''_{d*}} + I'_* \tag{35}$$

The following is obtained from formulae (27) and (10):

$$K''(t)_* = \sum_i K''(t)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_M} \tag{36}$$

$K''(t_x)_*$ may be obtained using formula (36) where $t = t_x$, then:

$$T''_{d*} = \frac{-t_x}{\ln\left[(K''(t_x)_* - I'_*)/M_*\right]} \tag{37}$$

(4) Determination of equivalent generator transient time constant T'_{d*}

The symmetric short-circuit current fed through the equivalent generator may be calculated using formula (33) where $t = t_x$:

$$I_{ac}(t_x)_* = M_* \cdot e^{-t_x/T''_{d*}} + N_* \cdot e^{-t_x/T'_{d*}} + I_{K*} \tag{38}$$

Similarly, $I_{ac}(t_x)_*$ may be obtained as follows:

$$I_{ac}(t_x)_* = \sum_i I_{acG}(t_x)_i + \sum_j I_{acM}(t_x)_j \tag{39}$$

Accordingly T'_{d*} may be obtained from:

$$T'_{d*} = \frac{-t_x}{\ln\{[I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T''_{d*}} + I_{K*})]/N_*\}} \tag{40}$$

(5) Determination of DC time constant T_{dc*}

The DC component of the short-circuit current fed through the equivalent generator for $t = t_x$ may be calculated as follows:

$$i_{dc}(t_x)_* = \sqrt{2} I''_* \cdot e^{-t_x/T_{dc*}} \tag{41}$$

and $i_{dc}(t_x)_*$ may be calculated also as follows:

$$i_{dc}(t_x)_* = \sum_i i_{dcG}(t_x)_i + \sum_j i_{dcM}(t_x)_j \tag{42}$$

Accordingly T_{dc*} may be calculated from:

$$T_{dc*} = \frac{-t_x}{\ln[i_{dc}(t_x)_*/(\sqrt{2} I''_*)]} \tag{43}$$

(6) Determination of impedances

Where the preload condition is ignored, the equivalent generator impedance may be obtained as follows:

$$R_* = \frac{1000 X''_*}{2\pi f T_{dc*}} \tag{44}$$

Assuming $C = \frac{1000}{2\pi f T_{dc*}}$,

Hence $R_* = C X''_*$

$$Z''_* = U_r/(\sqrt{3} I''_*) \tag{45}$$

$$Z'_* = U_r/(\sqrt{3} I'_*) \tag{46}$$

$$Z_* = U_r/(\sqrt{3} I_*) \tag{47}$$

Hence:

$$X''_* = \frac{Z''_*}{\sqrt{1 + C^2}} \tag{48}$$

$$X'_* = \sqrt{Z'^2_* - R_*^2} \tag{49}$$

$$X_* = \sqrt{Z_*^2 - R_*^2} \tag{50}$$

1.2.6.3 Calculation of the short-circuit current at the feeder outside the main bus-bar

(1) First, characteristic parameters of an equivalent generator at the main bus-bar are to be obtained in accordance with the above-mentioned requirements of 1.2.6.2. Then the short-circuit current at any point on the feeder outside the main bus-bar may be calculated in accordance with the requirements of 1.2.2 and 1.2.4.

(2) When the short-circuit current at the feeder of a large motor is calculated, the impact of the motor may not be taken into account.

1.2.6.4 Calculation of the short-circuit current at secondary side of transformers

(1) This belongs to one of the cases of the short circuit at the feeder outside the main bus-bar, only the transformer impedance is considered as one part of the circuit impedance (for impedance calculation see 1.4.2), and the changes of the transformer impedance are to be also considered.

1.2.7 Simplified calculation of short-circuit currents

1.2.7.1 Synchronous machines

(1) If the stator resistance is unavailable it may be ignored in formulae (3), (4), (5) and (6). For a short-circuit current calculated at the terminals of a machine, the result will be higher but well within

acceptable tolerances. For system calculations, the error is negligible.
(2) If the preload condition, I_0, is ignored, i.e. assuming a generator on no load in formulae (5), (6), (7) and (8), the values of E''_{q0} and E'_{q0} may be assumed to be equal to $U_r / \sqrt{3}$, and results in lower calculated value (generally less than 10%).
(3) If the transient AC component decay is ignored, formula (2) becomes:

$$I_{ac}(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + I'_{Kd} \tag{51}$$

Excessive inaccuracies occur in the peak short-circuit current for formula (51). Such inaccuracies will invalidate any results calculated beyond the first half-cycle of the fault condition, and accordingly this approximation is not recommended when time-dependent calculations are required.
(4) If the short-circuit current decay is ignored and stator resistance and preload current are ignored for the terminal short-circuit, the AC component of the short-circuit current may be assumed to be a ratio of a constant voltage divided by constant subtransient reactance and the DC component as a proportional constant, i.e.:

$$I_{ac} = U_r / \sqrt{3} X''_d \tag{52}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc} = 1.8(\sqrt{2} I_{ac}) \tag{53}$$

These assumptions are only to be made when estimating approximate values, as the results will produce excessive positive errors for calculations required beyond the first 0.5 cycles.
1.2.7.2 Asynchronous motors
(1) As a first approximation, it may be assumed that all asynchronous motors connected at the time of the short-circuit, contribute an AC short-circuit current equal to their starting current (usually 4 to 7 times the machine's normal full load current).
It may also be assumed that the motor contribution is constant throughout the complete short-circuit fault period.
Such assumptions will give higher values of short-circuit currents than will occur on the actual installation. The error will depend upon the number and size of motors connected.
(2) As above mentioned in 1.2.3.3(2) of this Appendix, if the preload condition is ignored when the short-circuit current of motors is calculated, the preload motor condition can be neglected with negligible errors.
(3) On the basis of asynchronous motor characteristic parameters given in 1.2.3.4(2) and 1.2.3.5(1) of this Appendix, the short-circuit current fed through the motor, with a short circuit occurring near the main bus-bar, may be calculated as follows:

① Large motors:

$I'_M = 6.25 I_{rM}$

$I_{acM} = 4.00 I_{rM}$ (for $t = T/2$)

$i_{pM} = 10 I_{rM}$

② Small motors:

$I''_M = 5 I_{rM}$

$I_{acM} = 3.2 I_{rM}$ (for $t = T/2$)

$i_{pM} = 8 I_{rM}$

(4) If insufficient data is available, the motor rated current may be evaluated using the following formula:

$$I_{rM} = \frac{P_{rM}}{\sqrt{3} \cdot U_{rM} \cdot \eta_M \cdot \cos\varphi_M} \tag{54}$$

where $\eta_M \cdot \cos\varphi_M$ may be calculated from the following formula:

$$\eta_M \cdot \cos\varphi_M = 0.76$$

(5) The short-circuit current of asynchronous motor designed to work in limited service, whose parameters are not completely known, may be calculated assuming the motor is in continuous service and operating at reduced power.

1.3 Calculation of Circuit Power Factor

1.3.1 General

1.3.1.1 The rated short-circuit breaking capacity of the circuit breaker is related to the short-circuit power factor for the interruption of power in the circuit, and the power factor of a short circuit near the main bus-bar on marine and offshore AC electrical installations is generally less than those used for circuit breaker short-circuit tests. Therefore, the short-circuit power factor is to be calculated and if necessary, the short-circuit breaking capacity of the selected breaker is to be converted in accordance with the conversion

coefficient provided by the manufacturer. If insufficient data are available, the method given in Appendix B of this Appendix can be used for conversion (not applicable to the circuit breaker with time delay).

1.3.2 Calculation of short-circuit power factor

1.3.2.1 For the short-circuit at a certain point in way of the feeder outside the main bus-bar, the short-circuit power factor during subtransient periods may be calculated using formula (55):

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}} \tag{55}$$

1.3.2.2 For the short-circuit near the main bus-bar, the short-circuit power factor during subtransient periods may be calculated in accordance with formula (55), but $R_e = 0$ and $X_e = 0$ are to be taken.

1.4 Calculation and Conversion for Reactance, Resistance and Impedance

1.4.1 Conversion for generator/motor reactance and resistance

(1) Conversion for subtransient reactance acting in the direct axis is as follows:

$$X''_d = x''_d \frac{U_r}{\sqrt{3} I_{rG}} = x''_d \frac{U^2_r}{S_{rG}} \tag{56}$$

(2) Transient reactance acting in the direct axis:

$$X'_d = x'_d \frac{U_r}{\sqrt{3} I_{rG}} = x'_d \frac{U^2_r}{S_{rG}} \tag{57}$$

(3) Conversion for stator resistance:

$$R_a = r_a \frac{U_r}{\sqrt{3} I_{rG}} = r_a \frac{U^2_r}{S_{rG}} \tag{58}$$

1.4.1.1 Conversion for generator reactance and resistance

1.4.1.2 Conversion for motor resistance and reactance

1.4.2 Calculation and conversion for transformer reactance, resistance and impedance

1.4.2.1 Calculation and conversion for transformer reactance and resistance may be carried out using the following formulae:

$$Z_T = u_K \frac{U^2_r}{S_{rT}} \tag{62}$$

$$R_T = P_K \frac{U^2_r}{S^2_{rT}} \tag{63}$$

$$X_T = \sqrt{Z_T^2 - R_T^2} \tag{64}$$

(1) Conversion for mot

$$R_T = r_T \frac{U^2_r}{S_{rT}} = u_R \frac{U_r^2}{S_{rT}} \tag{65}$$

$$X_T = x_T \frac{U^2_r}{S_{rT}} = u_X \frac{U_r^2}{S_{rT}} \tag{66}$$

$$R_s = r_s \frac{U_{rM}}{\sqrt{3} I_{rM}} = r_s \frac{U^2_{rM} \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}} \tag{60}$$

$$R_R = r_R \frac{U_{rM}}{\sqrt{3} I_{rM}} = r_R \frac{U^2_{rM} \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}} \tag{61}$$

1.4.3 Calculation for cable resistance and reactance

1.4.3.1 Cable reactance and resistance can be calculated using the following formulae:

$$R = rl / a \tag{67}$$

$$X = xl / a \tag{68}$$

Appendix A Examples of Calculation

A.1 The diagrammatic sketch of an electrical system

A.1.1 The diagrammatic sketch of an electrical system indicating the position of each fault point is as shown in Figure A.1.1

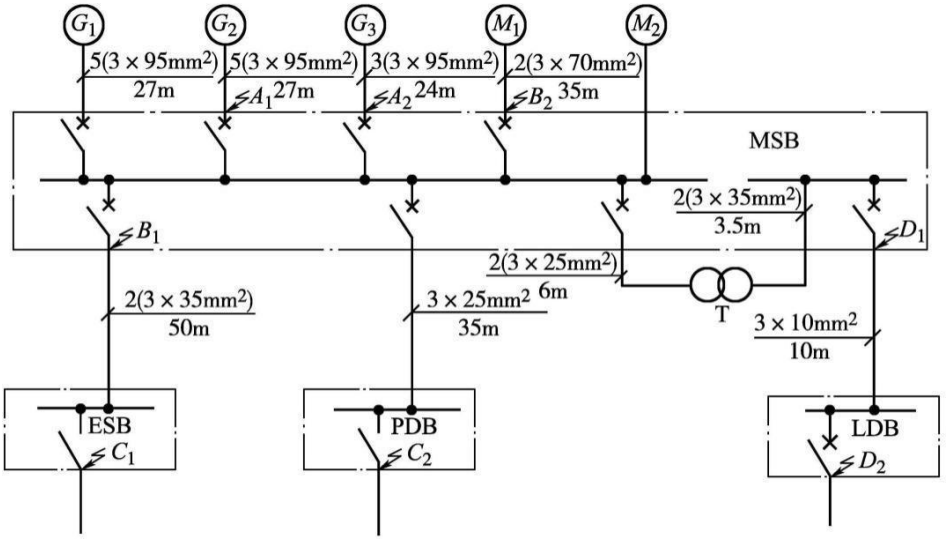


Figure A.1.1 Diagrammatic Sketch of Electrical System

A.2 Parameters for calculation

A.2.1 Generator parameters for calculation are given in Table A.2.1.

Generator Parameters **Table A.2.1**

Code	G_1, G_2	G_3
Type	IFC5502-8TA42	IFC5354-4
S_{rG} (kVA)	550	312.5
U_r (V)	400	400
I_{rG} (kA)	0.79	0.451
f (Hz)	50	50
x''_d	0.112	0.099
x'_d	0.193	0.17
x_d	2.19	3.16
r_a	0.0178	0.0174
T''_d(ms)	3	3
T'_d(ms)	80	49
T_{dc} (ms)	22	20
I_{Kd} (kA)	2.4	1.40

A.2.2 Transformer parameters for calculation are given in Table A.2.2.

Transformer Parameters **Table A.2.2**

Code	T
Type	CSGD-100
S_{rT} (kVA)	100
U_{rT2} (V)	230
u_K (%)	3.5
P_K (kW)	2.0

A.2.3 Motor parameters for calculation are given in Table A.2.3.

Motor Parameters **Table A.2.3**

Code	M_1	M_2 (Equivalent motor)
P_{rM} (kW)	120	408

Code	M_1	M_2 (Equivalent motor)
U_{rM} (V)	380	380
r_R	0.021	0.027
r_S	0.034	0.043
x''_M	0.15	0.188
T''_M (ms)	22.4	22.4
T_{dcM} (ms)	14.076	14.076

A.3 Calculation of the short-circuit current fed through the generator where the short-circuit occurs at the main bus-bar

A.3.1 Calculation of the impedance of cables connecting the generator to the main bus-bar

G_1, G_2:

$$R_e = rl / a = 0.215 \times 27 \div 5 = 1.161 \quad \text{m}\Omega$$

$$X_e = xl / a = 0.0809 \times 27 \div 5 = 0.437 \quad \text{m}\Omega$$

G_3:

$$R_e = rl / a = 0.215 \times 24 \div 3 = 1.72 \quad \text{m}\Omega$$

$$X_e = xl / a = 0.0809 \times 24 \div 3 = 0.647 \quad \text{m}\Omega$$

and resistance

A.3.2 Calculation of generator reactance

G_1, G_2:

$$X''_d = x''_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.112 \times 160000}{550} = 32.582 \quad \text{m}\Omega$$

$$X'_d = x'_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.193 \times 160000}{550} = 56.145 \quad \text{m}\Omega$$

$$X_d = x_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{2.19 \times 160000}{550} = 637.09 \quad \text{m}\Omega$$

$$R_e = r_a \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.0178 \times 160000}{550} = 5.18 \quad \text{m}\Omega$$

G_3:

$$X''_d = x''_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.099 \times 160000}{312.5} = 50.688 \quad \text{m}\Omega$$

$$X'_d = x'_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.17 \times 160000}{312.5} = 87.04 \quad \text{m}\Omega$$

$$X_d = x_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{3.16 \times 160000}{312.5} = 1617.92 \quad \text{m}\Omega$$

$$R_a = r_a \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.0174 \times 160000}{312.5} = 8.909 \quad \text{m}\Omega$$

A.3.3 Calculation of generator phase electromotive forces $\dot{E}''_{q0}$ and $\dot{E}'_{q0}$

G_1, G_2:

$$E''_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X''_d I_r\right)^2}$$

$$= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 32.582 \times 0.79\right)^2}$$

$$= 250.314 \text{ V}$$

$$E'_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X'_d I_r\right)^2}$$

$$= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 56.145 \times 0.79\right)^2}$$

$$= 262.908 \text{ V}$$

G_3:

$$E''_{q0}=\sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r+R_aI_r)^2+(\frac{U_r}{\sqrt{3}}\sin\varphi_r+X''_dI_r)^2}$$
$$=\sqrt{(\frac{400\times0.8}{\sqrt{3}}+8.909\times0.451)^2+(\frac{400\times0.6}{\sqrt{3}}+50.688\times0.451)^2}$$
$$=248.377\ \text{V}$$
$$E'_{q0}=\sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r+R_aI_r)^2+(\frac{U_r}{\sqrt{3}}\sin\varphi_r+X'_dI_r)^2}$$
$$=\sqrt{(\frac{400\times0.8}{\sqrt{3}}+8.909\times0.451)^2+(\frac{400\times0.6}{\sqrt{3}}+87.04\times0.451)^2}$$
$$=259.332\ \text{V}$$

A.3.4 Calculation of generator short-circuit currents

1 Calculations of $I''_{Kde}, I'_{Kde}, T''_e, T'_e$ and T_{dce}

(1) I''_{Kde} and I'_{Kde}

G_1, G_2:

$$I''_{Kde}=\frac{E''_{q0}}{\sqrt{(R_a+R_e)^2+(X''_d+X_e)^2}}$$
$$=\frac{250.314}{\sqrt{(5.18+1.161)^2+(32.582+0.437)^2}}$$
$$=7.445\ \text{kA}$$
$$I'_{Kde}=\frac{E'_{q0}}{\sqrt{(R_a+R_e)^2+(X'_d+X_e)^2}}$$
$$=\frac{262.908}{\sqrt{(5.18+1.161)^2+(56.145+0.437)^2}}$$
$$=4.618\ \text{kA}$$

G_3:

$$I''_{Kde}=\frac{E''_{q0}}{\sqrt{(R_a+R_e)^2+(X''_d+X_e)^2}}$$
$$=\frac{248.377}{\sqrt{(8.909+1.72)^2+(50.688+0.647)^2}}$$
$$=4.738\ \text{kA}$$
$$I'_{Kde}=\frac{E'_{q0}}{\sqrt{(R_a+R_e)^2+(X'_d+X_e)^2}}$$
$$=\frac{259.332}{\sqrt{(8.909+1.72)^2+(87.04+0.647)^2}}$$
$$=2.936\ \text{kA}$$

(2) T''_e, T'_e and T_{dce}

G_1, G_2:

$$T''_e=\frac{[(R_a+R_e)^2+(X''_d+X_e)^2]\cdot X'_d\cdot T''_d}{[(R_a+R_e)^2+(X''_d+X_e)(X'_d+X_e)]\cdot X''_d}$$
$$=\frac{(40.208+1090.254)\times56.145\times3}{(40.208+33.019\times56.582)\times32.582}$$
$$=3.062\quad\text{ms}$$
$$T'_e=\frac{[(R_a+R_e)^2+(X'_d+X_e)^2]\cdot X_d\cdot T'_d}{[(R_a+R_e)^2+(X'_d+X_e)(X_d+X_e)]\cdot X'_d}$$

$$= \frac{(40.208+3201.523)\times 637.09\times 80}{(40.208+56.582\times 637.527)\times 56.145}$$
$$= 81.49 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc}+1000X_e/(2\pi fR_a)}{1+R_e/R_a}$$
$$= \frac{22+1000\times 0.437/(100\pi\times 5.18)}{1+1.161/5.18}$$
$$= 18.191 \quad \text{ms}$$

G_3:

$$T_e'' = \frac{[(R_a+R_e)^2+(X_d''+X_e)^2]\cdot X_d'\cdot T_d''}{[(R_a+R_e)^2+(X_d''+X_e)(X_d'+X_e)]\cdot X_d''}$$
$$= \frac{(112.9756+2635.282)\times 87.04\times 3}{(112.9756+4501.412)\times 50.688}$$
$$= 3.068 \quad \text{ms}$$

$$T_e' = \frac{[(R_a+R_e)^2+(X_d'+X_e)^2]\cdot X_d\cdot T_d'}{[(R_a+R_e)^2+(X_d'+X_e)(X_d+X_e)]\cdot X_d'}$$
$$= \frac{(112.9756+7689.01)\times 1617.92\times 49}{(112.9756+87.687\times 1618.567)\times 87.04}$$
$$= 50.03 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc}+1000X_e/(2\pi fR_a)}{1+R_e/R_a}$$
$$= \frac{20+1000\times 0.647/(100\pi\times 8.909)}{1+1.72/8.909}$$
$$= 16.957 \quad \text{ms}$$

2 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

G_1, G_2:

$$I_{acG} = (I_{Kde}'' - I_{Kde}')\cdot e^{-t/T_e''} + (I_{Kd}' - I_{Kd})\cdot e^{-t/T_e'} + I_{Kd}$$
$$= (7.445-4.618)\cdot e^{-10/3.062} + (4.618-2.4)\cdot e^{-10/81.49} + 2.4$$
$$= 4.47 \text{ kA}$$
$$i_{dcG} = \sqrt{2}(I_{Kde}'' - I_r\cdot\sin\varphi_r)\cdot e^{-t/T_{dce}}$$
$$= \sqrt{2}(7.445-0.79\times 0.6)\cdot e^{-10/18.191}$$
$$= 5.689 \text{ kA}$$
$$i_{pG} = \sqrt{2}I_{acG} + i_{dcG}$$
$$= \sqrt{2}\times 4.47 + 5.689$$
$$= 12.01 \text{ kA}$$

G_3:

$$I_{acG} = (I_{Kde}'' - I_{Kde}')\cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kd})\cdot e^{-t/T_e'} + I_{Kd}$$
$$= (4.738\text{-}2.936)\cdot e^{-10/3.068} + (2.936-1.4)\cdot e^{-10/50.03} + 1.4$$
$$= 2.727 \text{ kA}$$
$$i_{dcG} = \sqrt{2}(I_{Kde}'' - I_r\cdot\sin\varphi_r)\cdot e^{-t/T_{dce}}$$
$$= \sqrt{2}(4.738-0.451\times 0.6)\cdot e^{-10/16.957}$$
$$= 3.503 \text{ kA}$$
$$i_{pG} = \sqrt{2}I_{acG} + i_{dcG}$$
$$= \sqrt{2}\times 2.727 + 3.503$$
$$= 7.36 \text{ kA}$$

A.4 Calculation of the short-circuit current fed through the motor where the short-circuit occurs at the main bus-bar

A.4.1 Calculation of impedance

A.4.1.1 The impedance of large motor M_1

1 Calculation of X''_M, R_S and R_R

$$X''_M = x''_M \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= \frac{0.15 \times 380^2 \times 0.76}{120}$$
$$= 137.18 \quad \text{m}\Omega$$
$$R_S = r_S \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.034 \times 914.533$$
$$= 31.094 \quad \text{m}\Omega$$
$$R_R = r_R \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.021 \times 914.533$$
$$= 19.205 \quad \text{m}\Omega$$

2 Cable impedance from the motor to the main bus-bar

$$R_e = rl / a$$
$$= 0.279 \times 35 \div 2$$
$$= 5.198 \quad \text{m}\Omega$$
$$X_e = xl / a$$
$$= 0.0821 \times 35 \div 2$$
$$= 1.437 \quad \text{m}\Omega$$

A.4.1.2 The impedance of equivalent motor M_2

$$X''_M = x''_M \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.188 \times \frac{380^2 \times 0.76}{408}$$
$$= 50.568 \quad \text{m}\Omega$$
$$R_S = r_S \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.043 \times 268.98$$
$$= 11.566 \quad \text{m}\Omega$$
$$R_R = r_R \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.027 \times 268.98$$
$$= 7.262 \quad \text{m}\Omega$$

A.4.2 Calculation of time constants for large motor M_1

$$T''_{Me} = \frac{1000 X''_{Me}}{2\pi f R_R}$$
$$= \frac{1000(X''_M + X_e)}{2\pi f R_R}$$
$$= \frac{1000 \times (137.18 + 1.437)}{100\pi \times 19.205}$$
$$= 22.975 \quad \text{ms}$$
$$T_{dcMe} = \frac{1000(X''_M + X_e)}{2\pi f (R_s + R_e)}$$
$$= \frac{10 \times 138.617}{\pi \times (31.094 + 5.198)}$$
$$= 12.158 \quad \text{ms}$$

A.4.3 Calculation of short-circuit currents

A.4.3.1 Where t = 10 ms, the short-circuit current of large motor M_1 is to be calculated as follows:

$$I''_{Me} = \frac{U_{rM}}{\sqrt{3}\sqrt{(R_R + R_S + R_e)^2 + (X''_M + X_e)^2}}$$
$$= \frac{380}{\sqrt{3} \times \sqrt{(19.205 + 31.094 + 5.198)^2 + (137.18 + 1.437)^2}}$$
$$= 1.469 \quad \text{kA}$$
$$I_{acM} = I''_{Me} \cdot e^{-t/T''_{Me}}$$
$$= 1.469 \times e^{-10/22.975}$$
$$= 0.951 \quad \text{kA}$$
$$i_{dcM} = \sqrt{2} I''_{Me} \cdot e^{-t/T''_{dcMe}}$$
$$= \sqrt{2} \times 1.469 \times e^{-10/12.158}$$
$$= 0.913 \quad \text{kA}$$
$$i_{pM} = \sqrt{2} I_{acM} + i_{dcM}$$
$$= \sqrt{2} \times 0.951 + 0.913$$
$$= 2.258 \quad \text{kA}$$

A.4.3.2 Where t = 10 ms, the short-circuit current of the equivalent motor (small motor group) M_2 is to be calculated as follows:

$$I''_{Me} = \frac{U_{rM}}{\sqrt{3}\sqrt{(R_S + R_R)^2 + X''^2_M}}$$
$$= \frac{380}{\sqrt{3} \times \sqrt{(11.566 + 7.262)^2 + 50.568^2}}$$
$$= 4.066 \quad \text{kA}$$
$$I_{acM} = I''_{Me} \cdot e^{-t/T''_{Me}}$$
$$= 4.066 \times e^{-10/22.4}$$
$$= 2.602 \quad \text{kA}$$
$$i_{dcM} = \sqrt{2} I''_{Me} \cdot e^{-t/T_{dcMe}}$$
$$= \sqrt{2} \times 4.066 \times e^{-10/14.076}$$
$$= 2.826 \quad \text{kA}$$
$$i_{pM} = \sqrt{2} I_{acM} + i_{dcM}$$
$$= \sqrt{2} \times 2.602 + 2.826$$
$$= 6.506 \quad \text{kA}$$

A.5 Calculation of short-circuit currents at points A_1, A_2, B_1 and B_2

A.5.1 Calculation of the short-circuit current at point A_1

A.5.1.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG3} + I_{acM1} + I_{acM2}$$
$$= 4.47 + 2.727 + 0.951 + 2.602$$
$$= 10.75 \quad \text{kA}$$
$$i_p = i_{pG1} + i_{pG3} + i_{pM1} + i_{pM2}$$
$$= 12.01 + 7.36 + 2.258 + 6.506$$
$$= 28.134 \quad \text{kA}$$

A.5.2 Calculation of the short-circuit current at point A_2

A.5.2.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acM1} + I_{acM2}$$
$$= 2 \times 4.47 + 0.951 + 2.602$$
$$= 12.493 \quad \text{kA}$$
$$i_p = i_{pG1} + i_{pG2} + i_{pM1} + i_{pM2}$$

$= 2 \times 12.01 + 2.258 + 6.506$
$= 32.784$ kA

A.5.3 Calculation of the short-circuit current at point B_1

A.5.3.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM1} + I_{acM2}$$
$= 2 \times 4.47 + 2.727 + 0.951 + 2.602$
$= 15.22$ kA

$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM1} + i_{pM2}$$
$= 2 \times 12.01 + 7.36 + 2.258 + 6.506$
$= 40.144$ kA

A.5.4 Calculation of the short-circuit current at point B_2

A.5.4.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM2}$$
$= 2 \times 4.47 + 2.727 + 2.602$
$= 14.269$ kA

$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM2}$$
$= 2 \times 12.01 + 7.36 + 6.506$
$= 37.886$ kA

A.6 Calculation of short-circuit currents at points C_1, C_2, D_1 and D_2

A.6.1 Determination of parameters of the equivalent generator where t = 10 ms

A.6.1.1 The determination of subtransient time constant T''_{d*}

1 It may be calculated from formulae (29), (30) and (31):

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej}$$
$= 2 \times 7.445 + 4.738 + 1.469 + 4.066$
$= 25.163$ kA

$$I'_* = \sum_i I'_{Kdei}$$
$= 2 \times 4.618 + 2.936$
$= 12.172$ kA

$$I_{K*} = \sum_i I_{Kdi}$$
$= 2 \times 2.4 + 1.4$
$= 6.2$ kA

Hence: $M_* = I''_* - I'_*$
$= 25.163 - 12.172$
$= 12.991$ kA

$N_* = I'_* - I_{K*}$
$= 12.172 - 6.2$
$= 5.972$ kA

2 Where t_x = 10 ms, $K''(t)$ and $K''(t)_*$ of G_1, G_2 and G_3 are to be calculated from formulae (34) and (36)

G_1, G_2:

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$
$= (7.445\text{-}4.618) \cdot e^{-10/3.062} + 4.618$
$= 4.726$ kA

G_3:

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$
$= (4.738\text{-}2.936) \cdot e^{-10/3.068} + 2.936$
$= 3.005$ kA

Hence: $K''(t_x)_* = \sum_i K''(t_x)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_{Me}}$

$$= 2 \times 4.726 + 3.005 + 0.951 + 2.602$$
$$= 16.01 \quad \text{kA}$$

3 Hence:

$$T''_{d*} = \frac{-t_x}{\ln\left[(K''(t_x)_* - I'_*)/M_*\right]}$$
$$= \frac{-10}{\ln\left[(16.01-12.172)/12.991\right]}$$
$$= 8.20 \quad \text{ms}$$

A.6.1.2 The determination of transient time constant T'

Where t_x = 10 ms, it is to be calculated from formula (39):

$$I_{ac*} = \sum_i I_{acGi} + \sum_j I_{acMj}$$
$$= 15.22 \quad \text{kA (i.e. the value of } I_{ac} \text{ at point } B_1)$$

Hence:

$$T'_{d*} = \frac{-t_x}{\ln\left[\frac{I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T''_{d*}} + I_{k*})}{N_*}\right]}$$
$$= \frac{-10}{\ln\left[\frac{15.22 - (12.991 \times e^{-10/8.20} + 6.2)}{5.972}\right]}$$
$$= 70.553 \quad \text{ms}$$

A.6.1.3 The determination of DC time constant T_{dc*}

Where t_x = 10 ms, it is to be calculated from formula (42):

$$i_{dc}(t_x)_* = \sum_i i_{dcGi} + \sum_j i_{dcMj}$$
$$= 2 \times 5.689 + 3.503 + 0.913 + 2.826$$
$$= 18.62 \quad \text{kA}$$

Hence:

$$T_{dc*} = \frac{-t_x}{\ln\left[\frac{i_{dc}(t_x)_*}{\sqrt{2}I''_*}\right]}$$
$$= \frac{-10}{\ln\left[\frac{18.62}{\sqrt{2} \times 25.163}\right]}$$
$$= 15.439 \quad \text{ms}$$

A.6.1.4 The determination of impedance

It may be calculated from formulae (45), (46) and (47):

$$Z''_* = \frac{U_r}{\sqrt{3}I''_*} = \frac{400}{\sqrt{3} \times 25.163} = 9.178 \quad \text{m}\Omega$$

$$Z'_* = \frac{U_r}{\sqrt{3}I'_*} = \frac{400}{\sqrt{3} \times 12.172} = 18.973 \quad \text{m}\Omega$$

$$Z_* = \frac{U_r}{\sqrt{3}I_{K*}} = \frac{400}{\sqrt{3} \times 6.2} = 37.248 \quad \text{m}\Omega$$

and

$$C = \frac{1000}{2\pi f T_{dc*}} = \frac{10}{\pi \times 15.439} = 0.2062 \quad \text{m}\Omega$$

Hence:

$$X''_* = \frac{Z''_*}{\sqrt{1+C^2}} = \frac{9.178}{\sqrt{1+0.2062^2}} = 8.99 \quad \text{m}\Omega$$

$$R_* = CX''_* = 0.2062 \times 8.99 = 1.854 \quad \text{m}\Omega$$

$$X'_* = \sqrt{Z'^2_* - R_*^2} = \sqrt{18.973^2 - 1.854^2} = 18.88 \quad \text{m}\Omega$$

$$X_* = \sqrt{Z_*^2 - R_*^2} = \sqrt{37.248^2 - 1.854^2} = 37.202 \quad \text{m}\Omega$$

A.6.2 Calculation of the short-circuit current at point C_1

A.6.2.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl/a = 0.582 \times 50/2 = 14.55 \quad \text{m}\Omega$$

$$X_e = xl/a = 0.0871 \times 50/2 = 2.178 \quad \text{m}\Omega$$

A.6.2.2 The calculation of $T_e^{''}, T_e^{'}$ and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$

$$= \frac{[(1.854+14.55)^2 + (8.99+2.178)^2] \times 18.88 \times 8.20}{[(1.854+14.55)^2 + (8.99+2.178)(18.88+2.178)] \times 8.99}$$

$$= 13.449 \quad \text{ms}$$

$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$

$$= \frac{[(1.854+14.55)^2 + (18.88+2.178)^2] \times 37.202 \times 70.553}{[(1.854+14.55)^2 + (18.88+2.178)(37.202+2.178)] \times 18.88}$$

$$= 90.186 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*}$$

$$= \frac{15.439 + 1000 \times 2.178 / (100\pi \times 1.854)}{1 + 14.55/1.854}$$

$$= 2.168 \quad \text{ms}$$

A.6.2.3 The calculation of $I_{Kde}^{''}$, $I_{Kde}^{'}$ and I_{Kde}

$$I_{Kde}^{''} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*^{''} + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854+14.55)^2 + (8.99+2.178)^2}}$$

$$= 11.637 \quad \text{kA}$$

$$I_{Kde}^{'} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*^{'} + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854+14.55)^2 + (18.88+2.178)^2}}$$

$$= 8.652 \quad \text{kA}$$

$$I_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854+14.55)^2 + (37.202+2.178)^2}}$$

$$= 5.413 \quad \text{kA}$$

A.6.2.4 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I_{Kde}^{''} - I_{Kde}^{'}) \cdot e^{-t/T_e^{''}} + (I_{Kde}^{'} - I_{Kde}) \cdot e^{-t/T_e^{'}} + I_{Kde}$$

$$= (11.637 - 8.652) \cdot e^{-10/13.449} + (8.652 - 5.413) \cdot e^{-10/90.186} + 5.413$$

$$= 9.731 \quad \text{kA}$$

$$i_{dc} = \sqrt{2} I_{Kde}^{''} \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 11.637 \times e^{-10/2.168}$$

$$= 0.163 \quad \text{kA}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 9.731 + 0.163$$
$$= 13.925 \quad \text{kA}$$

A.6.3 Calculation of the short-circuit current and power factor at point C_2

A.6.3.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl / a = 0.807 \times 35 = 28.245 \quad \text{m}\Omega$$
$$X_e = xl / a = 0.0855 \times 35 = 3.098 \quad \text{m}\Omega$$

A.6.3.2 The calculation of T'', T' and T

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$
$$= \frac{[(1.854 + 28.245)^2 + (8.99 + 3.098)^2] \times 18.88 \times 8.20}{[(1.854 + 28.245)^2 + (8.99 + 3.098)(18.88 + 3.098)] \times 8.99}$$
$$= 15.464 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$
$$= \frac{[(1.854 + 28.245)^2 + (18.88 + 3.098)^2] \times 37.202 \times 70.553}{[(1.854 + 28.245)^2 + (18.88 + 3.098)(37.202 + 3.098)] \times 18.88}$$
$$= 107.775 \quad \text{ms}$$
$$T_{dce} = \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*}$$
$$= \frac{15.439 + 1000 \times 3.098 / (100\pi \times 1.854)}{1 + 28.245 / 1.854}$$
$$= 1.28 \quad \text{ms}$$

A.6.3.3 The calculation of I''_{Kde}, I'_{Kde} and I^{dce}_{Kde}

$$I''_{Kde} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}}$$
$$= 7.12 \quad \text{kA}$$
$$I'_{Kde} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (18.88 + 3.098)^2}}$$
$$= 6.197 \quad \text{kA}$$
$$I_{Kde} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (37.202 + 3.098)^2}}$$
$$= 4.591 \quad \text{kA}$$

A.6.3.4 Where: t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T_e''} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T_e'} + I_{Kde}$$
$$= (7.12 - 6.197) \cdot e^{-10/15.464} + (6.197 - 4.591) \cdot e^{-10/107.775} + 4.591$$
$$= 6.538 \quad \text{kA}$$
$$i_{dc} = \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 7.12 \times e^{-10/1.28}$$
$$= 0.0041 \quad \text{kA}$$
$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 6.538 + 0.0041$$
$$= 9.25 \quad \text{kA}$$

A.6.4 Calculation of the short-circuit current at point D_1

A.6.4.1 The calculation of the circuit impedance from the main bus-bar to fault points

1. The primary circuit impedance of a transformer

$$R_{e1} = rl / a = 0.807 \times 6 / 2 = 2.421 \quad \text{mΩ}$$
$$X_{e1} = xl / a = 0.0885 \times 6 / 2 = 0.2655 \quad \text{Mω}$$

2. The calculation of the transformer impedance

$$Z_T = u_K \cdot \frac{U_r^{\ 2}}{S_{rT}}$$
$$= 3.5\% \times \frac{400^2}{100}$$
$$= 56 \quad \text{mΩ}$$
$$R_T = P_K \cdot \frac{U_r^{\ 2}}{S_{rT}^{\ 2}}$$
$$= 2.0 \times \frac{400^2}{100^2}$$
$$= 32 \quad \text{mΩ}$$
$$X_T = \sqrt{Z_T^{\ 2} - R_T^{\ 2}}$$
$$= \sqrt{56^2 - 32^2}$$
$$= 45.9565 \quad \text{mΩ}$$

3. The circuit impedance at the secondary side of the transformer as converted to the primary side

$$R_{e2} = (rl / a) \cdot (U_r / U_{rT2})^2$$
$$= (0.582 \times 3.5 / 2) \times (400 / 230)^2$$
$$= 3.0805 \quad \text{mΩ}$$
$$X_{e2} = (xl / a) \cdot (U_r / U_{rT2})^2$$
$$= (0.0871 \times 3.5/2) \times (400/230)^2$$
$$= 0.461 \quad \text{mΩ}$$

4. The circuit impedance from the main bus-bar to fault points

$$R_e = R_{e1} + R_T + R_{e2}$$
$$= 2.421 + 32 + 3.0805$$
$$= 37.5015 \quad \text{mΩ}$$
$$X_e = X_{e1} + X_T + X_{e2}$$
$$= 0.2655 + 45.9565 + 0.461$$
$$= 46.683 \quad \text{mΩ}$$

A.6.4.2 The calculation of T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$
$$= \frac{[(1.854 + 37.5015)^2 + (8.99 + 46.683)^2] \times 18.88 \times 8.20}{[(1.854 + 37.5015)^2 + (8.99 + 46.683)(18.88 + 46.683)] \times 8.99}$$
$$= 15.397 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$
$$= \frac{[(1.854 + 37.5015)^2 + (18.88 + 46.683)^2] \times 37.202 \times 70.553}{[(1.854 + 37.5015)^2 + (18.88 + 46.683)(37.202 + 46.683)] \times 18.88}$$

$$= 115.328 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc*} + 1000X_e/(2\pi f R_*)}{1 + R_e/R_*}$$

$$= \frac{15.439 + 1000 \times 46.683/(100\pi \times 1.854)}{1 + 37.5015/1.854}$$

$$= 4.503 \quad \text{ms}$$

A.6.4.3 The calculation of I''_{Kde}, I'_{Kde} and I_{Kde}

$$I''_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}}$$

$$= 3.387 \quad \text{kA}$$

$$I'_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X'_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (18.88 + 46.683)^2}}$$

$$= 3.02 \quad \text{kA}$$

$$I_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (37.202 + 46.683)^2}}$$

$$= 2.492 \quad \text{kA}$$

A.6.4.4 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T'_e} + I_{Kde}$$

$$= (3.387 - 3.02) \cdot e^{-10/15.397} + (3.02 - 2.492) \cdot e^{-10/115.328} + 2.492$$

$$= 3.168 \quad \text{kA}$$

$$i_{dc} = \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 3.387 \times e^{-10/4.503}$$

$$= 0.52 \quad \text{kA}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc}$$

$$= \sqrt{2} \times 3.168 + 0.52$$

$$= 5.0 \quad \text{kA}$$

The short-circuit current at the secondary side of a transformer

$$I_{ac2} = I_{ac}(U_r/U_{rT2})$$

$$= 3.168 \times 400/230$$

$$= 5.51 \text{ kA}$$

$$i_{p2} = i_p(U_r/U_{rT2})$$

$$= 5.0 \times 400/230$$

$$= 8.696 \quad \text{kA}$$

A.6.5 Calculation of the short-circuit current at point D_2

A.6.5.1 The calculation of the circuit impedance from the main bus-bar to fault points

1 The circuit impedance from the main bus-bar to the lighting bus-bar (i.e. the impedance at point D_1)

$R_e = 37.5015$ mΩ

$X_e = 46.683$ mΩ

2 The circuit impedance from the lighting bus-bar to fault points as converted to the primary side of the transformer

$$R_{e2} = (rl/a)\cdot(U_r/U_{rT2})^2$$
$$= (2.02 \times 10/1)\times(400/230)^2$$
$$= 61.096 \quad \text{m}\Omega$$
$$X_{e2} = (xl/a)\cdot(U_r/U_{rT2})^2$$
$$= (0.0957\times 10/1)\times(400/230)^2$$
$$= 2.895 \quad \text{m}\Omega$$

3 The circuit impedance from the main bus-bar to fault points

$$R_e = R_{e(D1)} + R_{e2}$$
$$= 37.5015 + 61.096$$
$$= 98.598 \quad \text{m}\Omega$$
$$X_e = X_{e(D1)} + X_{e2}$$
$$= 46.683 + 2.895$$
$$= 49.578 \quad \text{m}\Omega$$

A.6.5.2 The calculation of T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2]\cdot X_*'\cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)]\cdot X_*''}$$
$$= \frac{[(1.854 + 98.598)^2 + (8.99 + 49.578)^2]\times 18.88\times 8.20}{[(1.854 + 98.598)^2 + (8.99 + 49.578)(18.88 + 49.578)]\times 8.99}$$
$$= 16.513 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2]\cdot X_*\cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)]\cdot X_*'}$$
$$= \frac{[(1.854 + 98.598)^2 + (18.88 + 49.578)^2]\times 37.202\times 70.553}{[(1.854 + 98.598)^2 + (18.88 + 49.578)(37.202 + 49.578)]\times 18.88}$$
$$= 128.144 \quad \text{ms}$$
$$T_{dce} = \frac{T_{dc*} + 1000X_e/(2\pi f R_*)}{1 + R_e/R_*}$$
$$= \frac{15.439 + 1000\times 49.578/(100\pi\times 1.854)}{1 + 98.598/1.854}$$
$$= 1.89 \quad \text{ms}$$

A.6.5.3 The calculation of I_{Kde}'', I_{Kde}' and I_{Kde}

$$I_{Kde}'' = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}}$$
$$= 1.986 \quad \text{kA}$$
$$I_{Kde}' = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (18.88 + 49.578)^2}}$$
$$= 1.899 \quad \text{kA}$$
$$I_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (37.202 + 49.578)^2}}$$
$$= 1.74 \quad \text{kA}$$

A.6.5.4 Where t =10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T'_e} + I_{Kde}$$
$$= (1.986 - 1.899) \cdot e^{-10/16.513} + (1.899 - 1.74) \cdot e^{-10/128.144} + 1.74$$
$$= 1.931 \quad \text{kA}$$
$$i_{dc} = \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dce}}$$
$$= \sqrt{2} \times 1.986 \times e^{-10/1.89}$$
$$= 0.0141 \quad \text{kA}$$
$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 1.931 + 0.0141$$
$$= 2.745 \quad \text{kA}$$

The short-circuit current at the secondary side of a transformer

$$I_{ac2} = I_{ac}(U_r / U_{rT2})$$
$$= 1.931 \times 400/230$$
$$= 3.358 \quad \text{kA}$$
$$i_{p2} = i_p(U_r / U_{rT2})$$
$$= 2.745 \times 400/230$$
$$= 4.774 \quad \text{kA}$$

A.7 Calculation of short-circuit power factors

A.7.1 Calculation of short-circuit power factors at points A_1, A_2, B_1 and B_2.

$$\cos\varphi_K = \frac{R_*}{\sqrt{R_*^2 + X_*''^2}}$$
$$= \frac{1.854}{\sqrt{1.854^2 + 8.99^2}}$$
$$= 0.202$$

A.7.2 Calculation of short-circuit power factors at points C_1, C_2, D_1 and D_2

1 At point C_1:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 14.55}{\sqrt{(1.854 + 14.55)^2 + (8.99 + 2.178)^2}}$$
$$= 0.827$$

2 At point C_2:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 28.245}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}}$$
$$= 0.928$$

3 At point D_1:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 37.5015}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}}$$
$$= 0.577$$

4 At point D_2:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$

$$= \frac{1.854 + 98.598}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}}$$
$$= 0.864$$

A.8 A complete summary of results of short-circuit current calculation and data of selected protective devices

A.8.1 A complete summary of the results of the short-circuit current calculation and the data of the selected protective devices is given in Table A.8.1.

A Complete Summary of Results of Short-Circuit Current Calculation and Data of Selected Protective Devices **Table A.8.1**

Results of short-circuit current calculation					Selected protective devices								
Code of fault points	Time after occurrence of short-circuit	Symmetrical short-circuit current (kA)	Upper envelope of short-circuit current (kA)	Power factor of short-circuit current	Type	Rated current (A)	Rated voltage (V)	Rated short-circuit breaking capacity (kA)	Rated short-circuit making capacity (kA)	Rated short-time withstanding current (kA)	Power factor of short-circuit	$\cos\varphi_K$ conversion	
												Conversion coefficient	Short-circuit breaking capacity (kA)
A_1	T/2 Steady state	10.75 3.80	28.134	0.202	AH-10B	790	500	40	104	30 (1 s)			
A_2	T/2 Steady state	12.493 4.80	32.784	0.202	AH-6B	451	500	35	98.5	22 (1 s)			
B_1	T/2	15.22	40.144	0.202	TG-100B	50	500	42	95.5				
	T/2 Steady state	15.22 6.20	40.144	0.202	XH225NE①	150	415	25	50	5.0 (300 ms)			
	Steady state	6.20			XH600NE②	200	415			10.0 (300 ms)			
B_2	T/2	14.269	37.886	0.202	TO-225BA	225	500	22	44				
C_1	T/2	9.731	13.925	0.827	TO-100BA	15	500	18	38				
C_2	T/2	6.538	9.25	0.928	TO-100BA	15	500	18	38				
$D_1$③	T/2	5.51	8.696	0.577	TO-100BA	15	250	22	35				
D_2	T/2	3.358	4.774	0.864	TH-50B	10	250	5	8.6				

Notes:

① High-efficiency instantaneous trip breaker for the primary side of transformer T, with the transient current being 4 kA.

② Circuit breaker for feeders connecting main switchboard and emergency switch board.

③ Points D_1 and D_2 are short-circuit currents at the secondary side of the transformer.

Appendix B Conversion of Short-Circuit Breaking Capacity of Circuit Breaker

B.1 Foreword

The rated short-circuit breaking capacity of a circuit breaker is values provided by the manufacturer for the short-circuit breaking capacity corresponding to different rated operational voltages at the rated frequency and specified short-circuit power factor.

Because the sources of the short-circuit current in marine AC electrical systems are AC synchronous and asynchronous motors and the short-circuit power factor is small, the short-circuit power factors specified in standards for industrial circuit breakers cannot in general meet marine requirements.

This Appendix provides a method for conversion of the short-circuit breaking capacity where the given value of the test power factor of the selected breaker is not in compliance with the actual short-circuit power factor required for a marine electrical system.

B.2 Conversion method

The conversion is to be in accordance with the following steps:

a. The peak coefficient n corresponding to the given value of the test short-circuit power factor $\cos\varphi_{Kr}$ of the breaker may be obtained from Figure B.2.

Note: Where only the rated short-circuit making capacity and rated short-circuit breaking capacity of the breaker is given, the ratio of the rated short-circuit making capacity to the rated short-circuit breaking capacity is peak coefficient n.

b. The peak coefficient n' corresponding to the actually required short-circuit power factor $\cos\varphi_K$ may be obtained from Figure B.2.

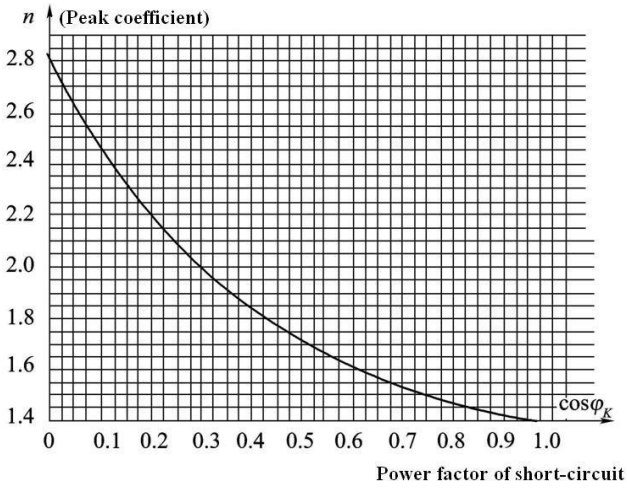


Figure B.2 Curve where Peak Value Coefficient $n = f(\cos\varphi_K)$

c. With the short-circuit power factor $\cos\varphi_K$, the short-circuit breaking capacity I_{Cr} of the breaker conversion is as follows:

$$I_{Cr} = \frac{n}{n'} I_{CR} = CI_{CR}$$

B.3 Example

It is assumed that the considered short-circuit power factor $\cos\varphi_K$ at the main bus-bar of a ship equals 0.16, and the known parameters of the selected TO-100BA circuit breaker are as follows:

Rated voltage: 500 V

Rated short-circuit breaking capacity: 18 kA

Rated short-circuit making capacity: 38 kA

Evaluation: The value of the short-circuit breaking capacity where the short-circuit power factor $\cos\varphi_K = 0.16$.

Solution:

(a) $n = \frac{38}{18} = 2.111$;

(b) $n' = 2.30$ where $\cos\varphi_K = 0.16$, as shown in Figure B.2;

(c) $I_{Cr} = \frac{n}{n'} I_{CR} = \frac{2.111}{2.30} \times 18 = 16.52$ kA.

APPENDIX 2 TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS

1.1 General design requirements

1.1.1 Ambient temperatures

Cable trays/protective casings are to be designed to the following ambient temperatures:

–25℃ to 90℃ for outdoor use;

+ 5℃ to 90℃ for indoor use.

Consideration will be given to the use of plastic cable trays/protective casings in the cold environment where the ambient temperature is below –25℃ provided the mechanical properties of the plastics can be maintained for the intended purpose and the installation location. In this particular instance, the cold bend and cold impact properties of the material are also to be considered.

1.1.2 Safe Working Load

Cable trays/protective casings are to be assigned a Safe Working Load in accordance with 2.2.2 of this Appendix.

1.2 Mechanical requirements

1.2.1 Impact resistance test

The test is to be performed according to IEC 60068-2-75 using the pendulum hammer.

1.2.1.1 The test is to be carried out on samples of cable tray lengths or cable ladder lengths, of 250 mm ±5 mm long. Samples of ladder are to consist of two side-members with one rung positioned centrally. Samples of mesh trays are to be prepared in such a way that there will be a wire in the centre.

1.2.1.2 Before the test, plastic components are to be aged at a temperature of 90℃ ±2℃ for 240 h continuously.

1.2.1.3 The samples are to be mounted on wooden fibreboard of thickness 20 mm ±2 mm.

1.2.1.4 The samples to be tested are to be placed in a refrigerator, the temperature within which is maintained at the declared temperature according to 1.1 above with a tolerance of ±2℃.

1.2.1.5 After 2 h, the samples are, in turn, to be removed from the refrigerator and immediately placed in the test apparatus.

1.2.1.6 At 10 s ±1 s after removal of each sample from the refrigerator, the hammer complying with Table 2.2.1.6 is to be allowed to fall with impact energy.

Hammer Specification **Table 2.2.1.6**

Approximate energy (J)	Mass of hammer (kg)	Fall height (mm)
10	5.0	200 ±2

2.2.1.7 The impact is to be applied to the base, or the rung, in the first sample, to one of the side members in the second sample, and to the other side member in the third sample. In each case, the impact is to be applied to the centre of the face being tested.

2.2.1.8 After the test, the samples are to show no signs of disintegration and/or deformation that will impair the safety.

1.2.2 Safe Working Load (SWL) test

1.2.2.1 Cable trays/protective casings and joints are to be assigned a Safe Working Load (SWL) satisfying the following criteria, tested at the declared temperatures according to 2.1.1 above (see note):

- the maximum deflection is not to exceed $L/100$, where L is the distance between the supports,
- no mechanical defects or failure are observed when tested to 1.7 × SWL.

1.2.2.2 All loads are to be uniformly distributed (UDL) over the length and width of the samples as shown in Figure 2.2.2.2.

The loads are to be applied in such a way that a UDL is ensured even in the case of extreme deformation of the samples.

To allow for settlement of the samples, a preload of 10% of the test load unless otherwise specified, is to be applied and held for at least 5 min, after which the measurement apparatus is to be calibrated to zero.

1.2.2.3 The load is then to be gradually increased evenly longitudinally and transversely up to the test load continuously or when a continuous increase is impractical, the load may be increased by increments. These increments are not to exceed about a quarter of the safe working load. The load increments are to be distributed through the load plates longitudinally and transversely as evenly as is practical.

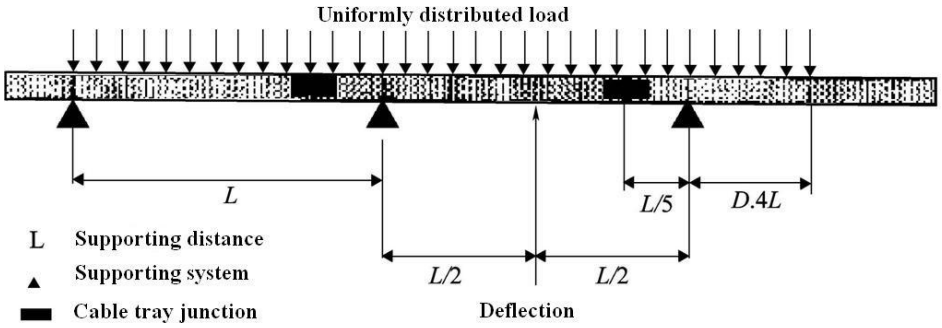


Figure 2.2.2.2 IEC 61537 Loading Test Procedure Summary

1.2.2.4 After loading, the deflection is to be measured at the points specified to give a practical mid-span deflection.

1.2.2.5 The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2 % with regard to the first set of the two consecutive sets of readings. The first set of readings measured at this point is the set of deflections measured at the test load.

1.2.2.6 When subject to the test load the samples, their joints and internal fixing devices, are to show no damage or crack visible to normal view or corrected vision without magnification.

1.2.2.7 The load is then to be increased to l.7 times the test load.

The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2% with regard to the first set of the two consecutive sets of readings. The samples are to sustain the increased loading without collapsing. Buckling and deformation of the samples is permissible at this loading.

Note: Alternatively, tests can be carried out:

- at any temperature within the declared range if documentation is available which states that the relevant structural properties of the materials as used within the system do not differ by more than 5% of the average between the maximum and minimum property values, or
- only at maximum temperature within the range, if documentation is available which states that the relevant structural properties of the materials as used within the system decrease when the temperature is increasing, or
- at maximum and minimum temperature only.

Tests are to be carried out for the smallest and largest sizes of cable tray lengths or cable ladder lengths, having the same material, joint and topological shape.

1.3 Fire properties

1.3.1 Flame retardant test

The cable trays/protective casings are to be at least flame retardant. They are to be tested in accordance with Table 2.3.1.

Flame Retardant Test

Table 2.3.1

Procedure according to	Test parameters	Other information
IEC 60092-101, or	– Flame application: 5 times 15 s each – Interval between each application: 15 s or 1 time 30 s	− The burnt out or damaged part of the specimen by not more than 60 mm long − Equipment design and the choice of materials is to reduce the likelihood of fire ensuring where surfaces of the specimen can be exposed to external fire they do not contribute to the fire growth
IEC60695-11-5	Test criteria based upon application	

1.3.2 Smoke and toxicity test

The cable trays/protective casings are to be tested in accordance with Part 2 of 2010 FTP Code adopted by IMO Resolution MSC.307(88) as amended by IMO Resolution MSC.437(99), or any international or national standard.

1.4 Special requirements

1.4.1 Resistivity test

Cable trays/protective casings passing through a hazardous area are to be electrically conductive. The volume resistivity level of the cable trays/protective casings and fittings is to be below 10^5 Ω and the surface resistivity is to be below 10^6 Ω. The cable trays/protective casings are to be tested in accordance with IEC62631-3-1 and IEC62631-3-2.
The resistance to earth from any point in these appliances is not to exceed 10^6 Ω.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART FIVE REFRIGERATED CARGO INSTALLATIONS

Table of Contents

CHAPTER 1 GENERAL 1
Section 1 GENERAL PROVISIONS 1
Section 2 TESTS 2
CHAPTER 2 REFRIGERATING PLANT 4
Section 1 GENERAL PROVISIONS 4
Section 2 REFRIGERATING MACHINERY 5
Section 3 PRESSURE VESSELS, PIPING, FITTINGS 6
AND ACCESSORIES 6
Section 4 CONTROL, ALARM AND SAFETY SYSTEMS 9
Section 5 LOCATION OF REFRIGERATING MACHINERY SPACE OR UNIT 10
Section 6 SAFETY DEVICES 12
CHAPTER 3 REFRIGERATED CARGO HOLDS/CHAMBERS 13
Section 1 DESIGN OF CARGO HOLDS/CHAMBERS 13
Section 2 ACCESSORIES 13
Section 3 INSULATION 15
CHAPTER 4 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS 16
Section 1 GENERAL PROVISIONS 16
Section 2 ARRANGEMENT 16
Section 3 VENTILATION WITHIN HOLDS 17
Section 4 ELECTRICAL INSTALLATIONS 18

CHAPTER 1GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 Ships with refrigerated cargo systems complying with the relevant requirements of Chapters 1 to 3 of this PART may be assigned the following class notations as appropriate:

CRS (× × Hold × ×℃, ××℃ Max. Sea Water)

— For ships fitted with refrigerated cargo installations, this notation is to be added after type notation, and minimum temperature(s) to be maintained by the installation at maximum sea water temperature stated and cargo area covered by the minimum temperature(s) are to be stated;

CF — For refrigerated installations for cargo fruits, this notation is to be added;

1.1.1.2 The certification requirements for and the products inspections related to refrigerated cargo systems are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

1.1.2 Refrigerants

1.1.2.1 The provisions of this PART are applicable to the refrigerants listed in Table 1.1.2.1:

Refrigerants Table 1.1.2.1

Refrigerant No.	Chemical formula or composition	Blending Ratio
R717	NH_3	-
R134a	$CH_2F\text{-}CF_3$	-
R404A	CHF_2CF_3(R125)/CH_3CF_3(R143a)/CH_2FCF_3(R134a)	（44%/52%/4%）
R407C	CH_2F_2(R32)/CHF_2CF_3(R125)/CH_2FCF_3(R134a)	(23%/25%/52%)
R410A	CH_2F_2(R32)/CHF_2CF_3(R125)	(50%/50%)
R507A	CHF_2CF_3(R125)/CH_3CF_3(R143a)	(50%/50%)

1.1.2.2 Where other refrigerants are to be used, relevant information is to be submitted for approval.

1.1.2.3 In addition, consideration is to be given to the relevant provisions for the application scope of refrigerants specified by the flag State Administration.

1.1.3 Operating conditions

1.1.3.1 The refrigeration systems are to operate satisfactorily when the ship is under the following conditions:

(1) permanent list up to 15º, and permanent trim up to 5º;

(2) rolling: 22.5º, and pitching: 7.5º.

1.1.3.2 Where the refrigerating units are provided with centralized control or automatic controlling and monitoring systems, the equipment of such systems is to comply with the relevant requirements of Chapter 2, PART SEVEN of the Rules.

1.1.4 Special cases

1.1.4.1 Any proposed addition to or relaxation of the requirements of this PART in respect to ships engaged on voyages of short duration, to installations of small capacity, or to other special cases is subject to agreement of ISC. In such cases a service limitation may be made to the ship.

1.1.4.2 Cargo chambers are in general not to be refrigerated by the direct expansion pipe grid system when R717 is used as refrigerant. However, in the case of a ship engaged in restricted service where the total capacity of its refrigerated cargo chambers is less than 500 m^3, a direct expansion ammonia pipe grid system may be adopted.

1.1.5 Plans and documents

1.1.5.1 The following plans and documents are to be submitted for approval. Where necessary, additional plans and documents may be required:

(1) General arrangement of insulated chambers (including neighbouring tanks and holds);

(2) Detailed plans showing the construction of insulation within refrigerated chambers;

(3) Details of insulation of piping and supports;

(4) General arrangement of refrigerating machinery space;

(5) Ventilation details of refrigerating machinery space;

(6) Arrangement of air cooling system;

(7) Arrangements of air cooler defrosting and drainage;
(8) Arrangement of brine grids or refrigerant grids in refrigerated chambers and method of construction;
(9) Piping diagrams of refrigerant, brine and cooling water systems;
(10) Arrangements of drainage and ventilation in refrigerated chambers;
(11) Arrangement of temperature measuring system in refrigerated chambers;
(12) Sectional arrangement and performance data of refrigeration compressors, detailed dimensioned plans of reciprocating compressor crankshafts;
(13) Plans of condensers, air and brine coolers, oil separators, liquid receivers and other pressure vessels;
(14) Schematic diagrams of automatic control, safety and alarm systems (including the specifications, types and functions).

1.1.5.2 The following plans and documents are to be submitted for information:
(1) Specifications for refrigerating plant (including centralized control and monitoring) and for insulation of refrigerated chambers;
(2) Calculations for refrigerating capacity.

Note: Plans and documents of the products which have been approved by ISC need not be resubmitted for approval.

1.1.6 Novel arrangement and construction

1.1.6.1 Where the proposed construction of the refrigerating unit or refrigerated chambers is novel in design or involves the use of unusual material, details are to be submitted for approval, and special tests may be required when necessary.

Section 2 TESTS

1.2.1 Pressure tests

1.2.1.1 Pressure tests after completion of manufacturing
(1) On completion of manufacturing, components and parts exposed to the pressure of the refrigerants are to be subject to strength and leak tests as detailed in Table 1.2.1.1.

Test Pressure **Table 1.2.1.1**

Component or part	Strength test (hydraulic)	Leak test (pneumatic)
Pressure vessels	1.5*p*	1.0*p*
Compressors:		
Cylinders	1.5*p*	1.0*p*
Crankcase	1.5*p*	1.0*p*
Valves and fittings	2.0*p*	1.0*p*
Pressure piping, welded fabricated headers, air coolers, etc.	1.5*p*	1.0*p*

Notes: ① *p* is the design pressure, see Table 2.1.4.1.
② The leak test normally requires an air pressure to be applied to the component while submerged in water. Alternative methods for leak test may be considered if practicable.

(2) Components exposed to the pressure of brine or cooling water are to be hydraulically tested to 1.5*p*, but in no case less than 0.34 MPa.
(3) For components not suitable for hydraulic pressure test, the relevant test program is to be submitted to ISC for approval if air pressure test is adopted in lieu of hydraulic pressure test.

1.2.1.2 Pressure tests after installation on board ship
(1) For pressure piping welded in place, hydraulic tests of the welds are to be carried out at a test pressure of 1.5*p*.
(2) For pressure piping welded in place, the hydraulic tests required in 1.2.1.2(1) may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out with satisfactory results on the entire circumferential butt welds.
Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a test report confirming that ultrasonic examination has been carried out and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.
(3) After completion of the test required in 1.2.1.2(1) or (2), a leak test is to be carried out at a pressure given in Table 1.2.1.1, and to be witnessed by the Surveyor on site.

1.2.1.3 After tightness testing and before charging with refrigerant and oil, the complete plant is to be dried by a method of evacuation. The plant is to be evacuated until the minimum absolute pressure is reached as far as practicable, which is to be held constant until all water is evaporated. The plant is then to be refilled with air and the same procedure is to be repeated until no water is left in the plant.

1.2.2 Operation tests

1.2.2.1 Preparations for tests

(1) Before the operation test, all thermometers or temperature measuring equipment fitted in the refrigerated chambers or on the refrigerating machinery are to be checked for accuracy, and a statement is to be given to the Surveyor. The Surveyor may require a random test if deemed necessary.

(2) Pressure gauges and other measuring instruments are, before the operation test, also to be checked to the satisfaction of the Surveyor.

1.2.2.2 Air cooler fans are to be tested under working conditions after the air circulating system has been completed. During the test, the static pressure of air outlet, the volume of air circulated per minute, the fan speed and the power consumption are to be recorded. The air circulation arrangements in the chambers are to be checked.

A statement of the results for each chamber is to be handed to the Surveyor on completion of tests.

1.2.2.3 Refrigeration tests

(1) All refrigerating units of the refrigeration system are to be subject to refrigeration tests under working conditions. The refrigeration test is to be carried out for a period of at least 12 h after the chamber temperatures have been lowered to the minimum temperature as required. However, the total time is not to be less than 24 h throughout the test.

In general, the refrigeration test may be carried out with all chambers empty. The hatch covers, access plugs or doors and air refreshing arrangements are to be closed up and liquid sealed traps for scuppers are to be primed with brine.

(2) At the beginning of the refrigeration test, all refrigerating units are to be put into action. After the chamber has been cooled down to the design temperature, the test may be carried on with one of the units out of action in turn in accordance with the requirements of 2.1.3, Chapter 2 of this PART, provided that the minimum required temperature in the chamber is maintained constant throughout the test. During the test, each unit is to operate for about the same time.

(3) Refrigeration systems are to be tested during a period when a reasonable difference between the external and internal temperatures exists.

1.2.2.4 Thermal balance tests

(1) During the refrigeration test of newly designed refrigeration systems, a thermal balance test is to be carried out to the plant in combination with the insulated chambers, so as to determine the minimum chamber temperature as required in the design and the running conditions when the chamber temperature and the capacity of the plant are balanced. The thermal balance test is to be carried out in the presence of the Surveyor.

(2) When the chambers are cooled down to the minimum designed temperature, the thermal balance test is to be commenced after such a temperature has been maintained constant for a stabilizing period during which heat is removed from the insulation etc. The heat balance test is to last for 8 h. During the test, the temperature of the chambers is to be maintained at the minimum designed temperature and is not to be reduced by more than 1℃. The thermal test may be evaluated in accordance with the relevant programme or standard accepted by ISC.

On completion of the thermal balance test, a thermal balance calculation is to be carried out and the calculations are to be submitted.

1.2.2.5 Temperature rise test for the refrigerated cargo chambers

With the chambers at the minimum designed temperatures, a test for the capability of insulation is to be carried out. The temperature rises in the chambers are to be logged hourly for a period of 6 h.

The total temperature rise t_G (average value of all measuring points) after 6 h temperature rise test is not to be greater than that obtained from the following formula based on the initial temperature difference between the external and chamber temperatures at the beginning of the temperature rise test:

$$t_G = 0.24 t_F \quad ℃$$

where: t_F — initial temperature difference between the external and chamber temperatures, in ℃.

1.2.2.6 Other tests

(1) The air refreshing arrangements, if fitted, are to be tested under operating conditions.

(2) The automatic monitoring system is to be subjected to operation test. This test is, in general, to be carried out when the refrigerating machinery is in running condition, but the functions of alarm and safety devices may be tested under simulated fault conditions if necessary.

(3) Prior to, or on completion of the refrigeration test, the defrosting arrangements of the air coolers are to be tested as per different methods of defrosting. The drainage of bilge water in refrigerated chambers and defrosting water from air coolers may be carried out in conjunction with the refrigeration test.

CHAPTER 2 REFRIGERATING PLANT

Section 1 GENERAL PROVISIONS

2.1.1 Definition of a unit

2.1.1.1 A refrigerating unit comprises one (or a group of) independent refrigeration compressor(s), its driving motor and one gas condenser. Where a secondary refrigerant of brine is employed, the unit is also to include a brine cooler. It is usual for the compressor and the condenser of the refrigerating plant to be permanently connected to the installation with all necessary piping, fittings and electrical equipment.

Two or more refrigeration compressors driven by a single motor, or having only one condenser or brine cooler, are to be regarded as one unit. Where a refrigerating plant is provided for sub-cooling the liquid refrigerant of other units, but is not arranged for cooling the cargo chambers independently, it will not be regarded as a unit.

2.1.1.2 Refrigerating units for refrigerated cargo installations must be completely independent of any refrigerating machinery associated with air conditioning plant, or any domestic refrigerated installation, unless otherwise approved by ISC.

2.1.2 Number of units

2.1.2.1 In ships intended for the carriage of refrigerated cargo, at least two complete refrigerating units are to be provided.

2.1.2.2 In ships classed for restricted service where the total capacity of the refrigerated chambers is less than 1,500 m^3, only one complete refrigerating unit may be provided, but a standby compressor is to be fitted as an addition.

2.1.3 Refrigerating capacity

2.1.3.1 Where a ship is classed for unrestricted service and is intended to carry cargoes requiring different refrigerating temperatures, the refrigerating capacity of the units is to be calculated according to the minimum temperature required to be maintained by the various cargo chambers, with the outside seawater temperature being assumed not less than 32℃.

2.1.3.2 The refrigerating capacity of the refrigerating plant is to be sufficient to maintain the minimum design temperatures in the refrigerated cargo chambers when operating 24 h per day with any one of the refrigerating units out of operation.

2.1.3.3 In order to compensate for possible deterioration of the refrigerating capacity of compressors and the performance of insulation material over the life of the installation, the actual capacity of the refrigerating units is to have at least 5% excess capacity over that required for maximum design output.

2.1.3.4 Where the units are not connected in common to all refrigerated chambers, the refrigerating capacity of the unit serving each chamber (or a group of chambers) is to comply with 2.1.3.2 and 2.1.3.3 of this Section.

2.1.4 Design pressure of refrigerating plant

2.1.4.1 The design pressure of the high pressure side and the low pressure side of the refrigerating plant is to be not less than the values given in Table 2.1.4.1 respectively.

Design Pressure of Refrigerating Plant **Table 2.1.4.1**

Refrigerant	Design pressure of high pressure side① (MPa)	Design pressure of low pressure side② (MPa)
R717	2.2	1.7
R134a	1.4	1.1
R404A	2.5	2.0
R407C	2.4	1.9
R410A	3.3	2.6
R507A	2.5	2.0

Notes: ① High pressure side means the pressed parts of the compressor between its exhausting side and expansion valve.

② Low pressure side means the pressed parts from behind the expansion valve to suction valve of the compressor. Where the change-over of the plant (e.g. for defrosting) will put these parts under high pressure, they are to be designed and tested to the specified pressure of high pressure side.

2.1.4.2 Where any other refrigerant is used, the design pressure of high pressure side and low pressure side of the refrigerating plant is to be not less than the saturated vapour pressure at 56℃ and 46℃ respectively.

Section 2 REFRIGERATING MACHINERY

2.2.1 Reciprocating compressors

2.2.1.1 The diameter d of the crankshaft of a reciprocating compressor is not to be less than that determined by the following formula, when all cranks are located between two main bearings:

$$d = C\sqrt[3]{\frac{D^2P(\frac{S}{16}+\frac{ab}{a+b})Z}{7.85}} \text{ mm}$$

where: C — constant, to be determined in accordance with the specific arrangement of cranks and cylinders as shown in Table 2.2.1.1.

D — diameter of compressor cylinder, in mm;

P — design pressure as defined in Table 2.1.4.1 of this Chapter, in MPa;

S — length of piston stroke, in mm;

a — distance between inner edge of one main bearing and the centreline of the crankpin nearest the center of the span, in mm;

$a + b$ — span between inner edges of two main bearings, in mm;

Z — strength coefficient of material, to be determined by the following formula:

For steel:

$$Z = \frac{560}{R_m + 160}$$

For spheroidal or nodular graphite cast iron:

$$Z = \frac{700}{R_m + 260 - 0.059d_p}$$

For grey cast iron:

$$Z = \frac{700}{R_m + 260 - 0.069d_p}$$

where: R_m — specified minimum tensile strength of crankshaft material, in N/mm^2;

d_p — proposed minimum diameter of crankshaft, in mm;

Arrangement of Cranks and Cylinders **Table 2.2.1.1**

Number of crankpins	Number of cylinders per crank	Angle between adjacent cylinders (°)
1 or 2	2	45 60 90
3	2	45 60
4	2	45 60
1	3	45 60 90
2	3	45 60
3	3	45
1	4	45 60
2	4	45

For shafts having one cylinder per crank:

C = 1.0

For shafts having several cylinders, with 90° between adjacent cylinders on the same crankpin:

C = 1.05

For shafts having several cylinders, with 60° between adjacent cylinders on the same crankpin:

C = 1.18

For shafts having several cylinders, with 45° between adjacent cylinders on the same crankpin:

C = 1.25

2.2.1.2 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by 6% for the full length shaft diameter.
2.2.1.3 The dimensions of crankwebs are to be such that bt^2 is to be not less than given by the following formulae:
For the web adjacent to the main bearing:

$$bt^2 = 0.4d^3$$

For intermediate webs:

$$bt^2 = 0.75d^3$$

where: b — breadth of web, in mm;

t — axial thickness of web which is to be not less than $0.45d$ for the web adjacent to the main bearing, or $0.60d$ for intermediate webs, in mm;

d — minimum diameter of crankshaft as required in 2.2.1.1 of this Section, in mm.

2.2.1.4 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius r not less than $0.05d$. Smaller fillets, but of a radius not less than $0.025d$, may be used provided the diameter of the shaft is not less than the product of c and d, where: $c = 1.1 - 2r/d$, but not to be taken as less than 1.0.
2.2.1.5 Fillets and oil holes on the crankshafts are to be rounded to an even contour and smooth finish.
2.2.1.6 The crankcase of a trunk piston type compressor is to be designed to withstand an internal pressure at least equal to the maximum working pressure of the refrigerating system.

2.2.2 Strength of materials for the compressor crankshafts

2.2.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following limits:
(1) carbon and carbon-manganese steel forgings (normalized and tempered): 400 to 600 N/mm^2;
(2) carbon and carbon-manganese steel forgings (quenched and tempered): not exceeding 700 N/mm^2;
(3) carbon and carbon-manganese steel castings: 400 to 550 N/mm^2;
(4) spheroidal or nodular graphite iron castings: 370 to 800 N/mm^2;
(5) grey iron castings: not less than 300 N/mm^2.
Where it is proposed to use materials other than those listed above, details are to be submitted to for approval.

Section 3 PRESSURE VESSELS, PIPING, FITTINGS AND ACCESSORIES

2.3.1 Pressure vessels

2.3.1.1 Among refrigerants specified in 1.1.2.1 of Chapter 1 of this PART, pressure vessels for refrigerants R717 are to be constructed in accordance with the relevant provisions for Class I pressure vessels specified in Chapter 6, PART THREE of the Rules, and in ISC Rules for Materials and Welding. Other pressure vessels for refrigerants are to comply with the relevant requirements for Class II pressure vessels. The design pressure of pressure vessels for refrigerants is to comply with the requirements of Table 2.1.4.1 of this Chapter.
2.3.1.2 Where pressure vessel cylinders are made of steel tubes, these are to be seamless, electrical resistance welded or longitudinally submerged arc welded. Forge butt welded and spirally welded tubes are not to be used.
2.3.1.3 All pressure vessels with a design temperature below -40℃ and also vessels with a design temperature below 0℃ where the pressure/saturation temperature relationship does not apply, are to be manufactured from steels with mechanical properties, including notch toughness, suitable for the thickness and the lowest design temperature, and relevant information is to be submitted.

2.3.2 Pressure piping

2.3.2.1 All steel pressure pipes for the refrigerating plant are to comply with the relevant provisions specified in Chapter 2, PART THREE of the Rules. Among refrigerants specified in 1.1.2.1 of Chapter 1 of this PART, piping for refrigerants R717 is to be considered as Class I piping and class of pipings for other refrigerants is to comply with the relevant requirements of 2.1.5 of Chapter 2 of PART THREE of the Rules.

2.3.2.2 Pipes for the condensers are to be made of corrosion-resistant material. Pipes for condensers suitable for refrigerants R134a are to be made of corrosion-resistant copper.
Condenser tube plates are to be made of corrosion-resistant material on the seawater side, or alternatively, means capable of efficiently protecting against corrosion may be used.
2.3.2.3 Materials used for refrigerant, brine or seawater cooling piping and accessories are to be suitable for use with the liquids flowing within the pipes. Copper, brass, bronze and other copper alloy are not to be used for ammonia refrigerant. Magnesium alloy is not to be used for fluorine-substituted hydrocarbon refrigerant, and zinc is not to be used for ammonia and fluorine-substituted hydrocarbon refrigerants.
2.3.2.4 Refrigerant and brine pipes are to be seamless, of which the ammonia and brine pipes are to be of seamless steel.
Pipe fittings for the ammonia unit are to be made of steel, but malleable cast iron may be accepted. Pipe fittings for the fluorine-substituted hydrocarbon unit are to be made of steel or bronze.
2.3.2.5 The joints of steel refrigerant pipes are to be butt welded. Where the piping is galvanized in lengths and then joined by welding, the galvanizing is to be removed in way of the pipe ends before welding. Butt joints of copper pipes are to be brazed. If necessary, a particular length of piping may be connected by means of welded-on flanges having grooves in a raised face and with gaskets fitted between them, or by means of screw joint sleeves.
The gaskets for the pipe joints are to be approved by ISC.
2.3.2.6 The stop valves in the refrigerant piping are to be so constructed and arranged as to ensure safe renewal of the packings in the valve stuffing boxes without removing the refrigerant. The stop valves in the R134a refrigerant piping are to be constructed without stuffing boxes. If safety valves with soft stuffing boxes are adopted, they are to be provided with sealing glands.

2.3.3 Oil separators
2.3.3.1 Suitable oil separators with drains are to be provided in the refrigerant lines. If wire gauze is used in the separator, it is to be sufficiently robust and supported to prevent disintegration.

2.3.4 Filters
2.3.4.1 Suitable filters are to be provided in the refrigerant gas lines in the following positions:
(1) suction lines to compressors;
(2) liquid lines before expansion valves.
Wire gauze in filters is to be sufficiently robust and well supported to prevent disintegration. The material of wire gauzes is to be corrosion-resistant to refrigerants. The refrigerant piping is to be designed according to the characteristics of refrigerants, and pipelines are to be fitted with suitable means for separating, storing and purifying refrigerants.
2.3.4.2 The filters are to be so installed and arranged that the filters may be repaired and maintained without interrupting the supply of refrigerants.

2.3.5 Driers
2.3.5.1 Driers are to be fitted in R134a refrigerant systems and the arrangement is to be such that a drier can be by-passed, isolated and opened up without interrupting plant operations.

2.3.6 Thermometers
2.3.6.1 Thermometers are to be provided in systems of the refrigerating plant in the following positions:
(1) suction and delivery lines to compressors;
(2) inlet and outlet cooling water lines to condensers;
(3) brine inlet and outlet lines;
(4) refrigerant return pipes to air coolers of direct expansion type.

2.3.7 Pressure gauges
2.3.7.1 Pressure gauges are to be provided in systems of the refrigerating plant in the following positions:
(1) suction and delivery lines to compressors;
(2) delivery lines to brine pumps;
(3) all refrigerant return pipes to air coolers;
(4) lubricating oil inlets to compressors with pressure lubrication.

2.3.8 Liquid receiver and liquid level indication
2.3.8.1 Refrigeration system is to be provided with necessary liquid receivers, the capacity of which is to be such that all refrigerants filled in the refrigerating unit may be received during the maintenance and

repairing. If independent liquid receiver is provided for each refrigerating unit, the capacity of receiver is to be capable of receiving the refrigerant filled in the refrigerating unit.

2.3.8.2 Refrigerant liquid receivers are to be provided with liquid level indicators. If the level indicator constructed of glass is used, it is to be of the flat glass type. The indicators are to be provided with self closing valves in lower and upper connections so as to prevent the loss of refrigerant in the event of breakage of the indicator. All liquid level indications are to be capable of withstanding the maximum working pressure.

2.3.9 Cooling appliances

2.3.9.1 Chambers may be refrigerated by pipe grids on the ceiling, bulkheads and sides or by the circulation of air over air coolers.

2.3.9.2 Except in the case of chambers employing direct expansion pipe grids as specified in 1.1.4.2 of this PART, refrigeration in the chambers is to be effected by the circulation of brine. The brine pipe grids in each chamber are to be arranged in not less than two sections, each section is to be provided with valve(s) or cock(s) for closing. For a refrigerated chamber with a capacity of less than 300 m^3, one section may be permitted.

2.3.9.3 Steel piping used to convey brine or primary refrigerants within the refrigerated cargo chambers, or where embedded in insulation, is to be galvanized externally. Alternative equivalent methods of protecting the piping against corrosion may be accepted.

Brine piping and tanks are not to be galvanized on the brine side. However, if any parts of the brine system have been galvanized, the brine cooling and return tanks, if closed, are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged, and the ventilating pipes are to be fitted with wire gauze diaphragms which can readily be renewed.

Where the brine tanks are not closed, the compartments in which they are situated are to be efficiently ventilated.

2.3.9.4 Where the steel pipes used to convey primary or secondary refrigerants are connected by butt welds or by screwed couplings, the ungalvanized portion of the joints is to be suitably coated and taped after hydraulic testing to reduce the incidence of corrosion. The locations of the joints are to be marked on the outside of the insulation.

2.3.9.5 Where cooling pipes pass through watertight bulkheads or decks, the construction of penetrations and packings are to comply with the requirements of 3.1.1.5 of this PART.

2.3.9.6 Either brine or direct expansion of the refrigerant may be employed in the coils of air coolers for each of the chambers. The coils are to be arranged in not less than two sections, each of which is to be fitted with a valve capable of being readily isolated when necessary. The chamber is to be provided with at least one air pipe length and two grids in a certain distance. If the coils are not arranged in sections, at least two independent air coolers of single coil are to be fitted.

A single coil cooler may be provided for a chamber with a net capacity of less than 300 m^3.

2.3.9.7 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the chambers are in service. The inside diameter of drains is not to be less than 40 mm.

2.3.9.8 Air coolers including fans and motors are to be, as far as practicable, separated from the refrigerated spaces loaded with cargo, and adequate space is to be provided such that both the fan and the motor may be readily removed for repair or renewal. Access for servicing only is required where several fans and motors are installed in a chamber.

2.3.9.9 In order to minimize the dehydration of the cargo and the frosting of the cooling appliances in the refrigerated cargo chambers, the plant is to be designed to maintain the required minimum temperature with a minimum of difference between the cooling medium and chamber temperatures.

2.3.10 Heating arrangements

2.3.10.1 Where it is intended to carry fruit cargoes which may be adversely affected by ambient temperatures which may be below the carrying temperatures, facilities for heating the cargo chambers are to be provided.

2.3.11 Air refreshing arrangements in cargo chambers

2.3.11.1 Where chambers are intended for the carriage of refrigerated cargoes requiring controlled ventilation, air refreshing means are to be provided. The positions of the air inlets are to be carefully selected to minimize the possibility of contaminated air entering the chambers. A distance of at least 3 m is to be maintained between inlet and exhaust vents so as to prevent them from being choked.

Chambers or spaces are to be provided with separate inlet and discharge vents. Each vent is to have a positive airtight valve capable of closing onto a seat.

2.3.12 Pumps

2.3.12.1 The refrigerating units are to be provided with at least two separate cooling water pumps, one of which may be a standby pump. This pump may be used for other purposes provided that it is of adequate capacity and its use on other services does not interfere with the supply of cooling water to the units.

2.3.12.2 Where the primary and/or secondary refrigerants are circulated in the system by pumps, a standby pump, which is not to be used for other purposes and capable of operating on all cargo chambers, is to be provided.

2.3.13 Sea connections

2.3.13.1 The refrigerant gas condenser cooling pump is to be supplied by two sea valves, one of which is provided on the port and the other on the starboard side.

2.3.14 Motive power

2.3.14.1 Where the refrigerating plant is electrically driven, the electrical power is to be supplied by at least two generators. Where any one of the generators is out of operation, the ratings of remaining generators are to be sufficient to maintain, at the seawater temperature specified in 2.1.3.1 of this Chapter, the required minimum temperatures specified in 2.1.3.2 or 2.1.3.3 of this Chapter for the refrigerated cargo chambers, and to ensure the simultaneous operation of other services essential for the propulsion and safety of the ship.

Section 4 CONTROL, ALARM AND SAFETY SYSTEMS

2.4.1 Automatic control for refrigerating plant

2.4.1.1 Where refrigerating plants are operated automatically, efficient manual controls are also to be provided so that manual control can be effected in the event of failure of the automatic control. The automatic control for the plant is to comply with the provisions set forth in 2.4.1.2 to 2.4.1.4 below.

2.4.1.2 The basic performances of all equipment in the refrigerating plant automatic control systems are to comply with the relevant requirements of Chapter 2, PART SEVEN of the Rules.

2.4.1.3 The refrigerating plant automatic control system is to cover the following:

(1) the control of the temperature in the refrigerated cargo chambers within the predetermined temperature limits;

(2) the control of the temperature of cooling air at the outlet not less than the minimum permissible temperatures when the chamber is air-cooled.

2.4.1.4 When the automatic thermostatic control mentioned in 2.4.1.3(1) above is changed over to manual control, the arrangement is to be such that thermostatic controls can be bypassed and isolated. As an alternative, duplicate thermostatically operated refrigerant control valves may be fitted, each valve is to be capable of the required duty and operable with the other out of action.

2.4.2 Alarm

2.4.2.1 The items of monitoring and alarms are not to be less than hose given in Table 2.4.2.1. Audible and visual fault alarms for the refrigerating plant are to be given at the appropriate control station or room.

Items of Monitoring and Alarms for the Refrigerating Plant① **Table 2.4.2.1**

No.	Item	Display	Alarm
1	Air temperature in the refrigerated cargo chambers	Temperature	High and low
2	Failure of air cooler fans	−	Failure
3	Bilge water level in the refrigerated cargo chambers	−	High
4	Condenser cooling water outlet temperature	Temperature	High
5	Compressor shutdown in the event of failure	−	Shutdown
6	Lubricating oil pressure of compressors	Pressure	Low
7	Suction pressure of compressors	Pressure	Low
8	Exhaust pressure of compressors	Pressure	High
9	Failure of seawater circulating pumps	−	Failure

No.	Item	Display	Alarm
10	Ammonia leakage in refrigerating machinery spaces	−	Leakage②
11	Brine cooler inlet and outlet	Temperature	High (outlet)
12	Failure of brine circulating pumps	−	Failure
13	Brine return tank level	−	Low

Note: ① Where the refrigerating machinery space is unattended, the fault alarms are to be relayed to the engineers' accommodation or other location where an engineer on duty stays.

② For setting of concentration for ammonia leakage alarm in refrigerating machinery space, see 2.5.5.3 of this Chapter.

2.4.3 Safety

2.4.3.1 The refrigerating plant is to be provided with safety systems to automatically shut down the compressors in the following events:

(1) excessively low pressure at the suction side of compressors;

(2) excessively high pressure at the delivery side of compressors;

(3) excessively low lubricating oil pressure in compressors;

(4) requirements specified in 2.5.5.3 of this Chapter for safety protection after ammonia leakage in the refrigerating machinery space;

(5) failure of seawater circulating pumps.

Section 5 LOCATION OF REFRIGERATING MACHINERY SPACE OR UNIT

2.5.1 Refrigerating machinery spaces

2.5.1.1 Where R717 is used as the refrigerant, the machinery compartment is to be isolated by gastight bulkheads and decks from any adjacent accommodation or working spaces.

2.5.1.2 Machinery using refrigerants other than R717 will not, in general, be subject to restriction on location. Where relatively large plants are adopted, they are to be installed in a separate compartment.

2.5.1.3 R717 is to be installed in dedicated gastight compartments. Except for small compartments, at least two access doors as apart from each other as possible, which are capable of being opened outwards and self-closed, are to be provided for R717 refrigerating machinery space.

2.5.1.4 In each R717 refrigerating machinery space at least two gas masks with canisters are to be provided near the entrance to that space and are to be kept in a box with glass window for immediate use when necessary.

2.5.1.5 The arrangements of the refrigerating machinery are to be such that all components are to be easily accessible for inspection or overhaul. Sufficient space is to be provided for cleaning and renewal of the tubes in brine coolers and condensers.

2.5.2 Ventilation and lighting

2.5.2.1 Any refrigerating machinery space is to be provided with an efficient mechanical ventilation system. The ventilation is to provide at least 30 air changes per hour in the refrigerating machinery space.

2.5.2.2 The suction ducts of the ventilation systems are to be constructed of steel or other equivalent material, and the exhaust ports of the ventilation systems are to be located in positions where no danger will arise. In the case of refrigerating machinery spaces other than R717, power exhaust ventilation systems are to be fitted with the suction inlets located at the lowest part of such spaces. Ventilation in R717 refrigerating machinery space is to comply with the relevant requirements in 2.5.3.1.

2.5.2.3 The mechanical ventilation for the refrigerating machinery space is to be capable of being controlled from two positions, and one of which is to be situated in a suitable position outside such space.

2.5.2.4 The fans in R717 refrigerating machinery space are to be of non-sparking type and the material and design of the fan are to comply with the requirements of 3.3.5 of Chapter 3, PART SIX of the Rules. Where the ventilation of R717 refrigerating machinery space is located within the ventilation corridor, the electrical motors are to be of certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1.

2.5.2.5 Sufficient lighting is to be provided in refrigerating machinery space. Lighting fittings required to be operating after the emergency shut-off of R717 refrigerating machinery space due to leakage of ammonia are to be of certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1 in accordance with 2.5.5.3(3) of this Chapter.

2.5.3 Use of R717 as a refrigerant

2.5.3.1 Compartments containing R717 machinery (including process vessels) are to be fitted with:

(1) a negative ventilation system independent of ventilation systems serving other ship spaces and the capacity of the refrigerating machinery space is to meet the requirements of 2.5.2.1; other suitable arrangements may be considered; Suction inlets of R717 refrigerating machinery space is to be located on the upper part of the compartment. The ventilation inlets of R717 refrigerating machinery space is to be from the safe area and the exhaust ports are to be lead to the safe location on the open deck;

(2) an emergency ventilation system independent of ventilation systems serving other ship spaces and the capacity of which is to provide at least 40 air changes per hour. If the capacity of the normal ventilation system in the refrigerating machinery space is increased to an amount of not less than 40 air changes per hour for that space, the emergency ventilation system may be dispensed with;

(3) if emergency water-spraying system is accepted in lieu of emergency ventilation system as equivalent, the emergency water-spraying system is to meet the requirements of 2.5.4 of this section; the emergency water-spraying system is to be capable of being operated from a position outside the refrigerating machinery space;

(4) a fixed R717 vapor detector system with alarms inside and outside the compartment;

(5) water screens above all access doors, operable manually from outside the compartment;

(6) an independent bilge system.

2.5.3.2 At least the following safety and protective equipment are to be provided outside of the R717 refrigerating machinery space and the storage location is to be marked for identification and restoration in the event of a refrigerant leak:

(1) two sets of protective clothing (helmet, face masks, boots, gloves etc.);

(2) two sets of independent respirators (at least for 30 min use);

(3) two goggles;

(4) two 30 kg bottles of boric acid;

(5) two emergency electric torches (to be certified safe type and the explosion groups and temperature classes are not to be lower than IIA T1);

(6) one electrical insulation resistance meter.

2.5.3.3 R717 piping is not to pass through accommodation spaces.

2.5.3.4 In case of R717 plants with a quantity of ammonia not greater than 25 kg, the plants are permitted to be located in the machinery space, provided that:

(1) the area where the R717 machinery is installed is served by a hood with a negative ventilation system, so as not to permit any leakage of ammonia from dissipating into other areas in the space;

(2) a water spray system is provided for the said area;

(3) the requirements in 2.5.3.1(2), 2.5.3.2(1) and 2.5.3.3 above are met.

2.5.4 Water-spraying system for R717 refrigerating machinery space

2.5.4.1 The system is to be independent and contains only fresh water, but may also be used for supply to the water screens.

2.5.4.2 The discharge nozzles in the space(s) protected are to be positioned such that the spray is directed over the entire area containing the ammonia refrigeration machinery. The spray volume of the water-spraying system is to be capable of absorbing the leaked ammonia.

2.5.4.3 The supply water of water-spraying system is to be pressurized. The pressurized system is to consist of two pumps and a tank which is to be fitted with adequate safety relief arrangements, pressure gauge(s), level control and level gauge.

2.5.4.4 Means are to be provided to automatically maintain the required pressure and the water level in the tank. In the event of low pressure or the low level, an audible alarm is to sound in the refrigeration machinery room and control room.

2.5.4.5 The water-spraying system is to be arranged to automatically start when the concentration of ammonia in the space exceeds 300 ppm.

2.5.4.6 If water-spraying system is fitted in the refrigerating machinery space, all electrical equipment in the space is to be to IP44 enclosure.

2.5.5 R717 vapor detection and alarm system

2.5.5.1 The detector is to be of a certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1 and to be suitable for the low temperature working environment.

2.5.5.2 The arrangement of R717 vapor detector is to meet the following requirements:

(1) The refrigerating machinery spaces; one detector per 36 m^2 of the space floor area.

(2) One detector in the exhaust duct of the refrigerating machinery space ventilation system.
(3) One detector in the access corridors leading to the ammonia refrigerating machinery spaces.
(4) One detector in the ammonia storage space.
2.5.5.3 The alarming and safety protection after detection of ammonia leak are to meet the following requirements:
(1) When the concentration of ammonia exceeds 25 ppm, the detectors are to activate alarms.
(2) When the concentration of ammonia exceeds 300 ppm, the detectors in the refrigerating machinery space are to automatically stop the refrigerating plant and automatically activate the emergency ventilation system.
(3) When the ammonia concentration exceeds 5000 ppm, all non-explosion proof electrical equipment in the refrigerating machinery space is to be cut off.

Section 6 SAFETY DEVICES

2.6.1 Relief valves and safety valves

2.6.1.1 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve. The safety devices are to come into action in case of excessive refrigerant pressure, the discharge being led to the suction side of the compressor. No closing appliances are to be permitted in the backflow pipes.
2.6.1.2 The opening pressure or bursting pressure of relief valves and/or safety discs at the delivery side of compressors is to be not greater than the design pressure of high pressure side given in Table 2.1.4.1, according to different refrigerants.
2.6.1.3 Where the power of the compressor prime mover does not exceed 10 kW, the relief valves and/or safety discs at the delivery side of the compressors may be omitted.
2.6.1.4 All pressure vessels or other components of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and/or relief valves, the discharge being led to a safe place above deck. When the safety disc is fitted in front of the relief valve, the back of the safety disc is to be provided with a bulwark to ensure the function of the relief valve. When the safety disc is fitted behind the relief valve, a pressure gauge indicating the intermediate pressure is to be fitted between the relief valve and the safety disc.
2.6.1.5 In the fluorine-substituted hydrocarbon systems, the safety valves and safety discs may be substituted by fusible plugs having a fusion point of 65℃, provided that the individual capacity of the above-mentioned pressure vessels is less than 100 *l*.
2.6.1.6 The opening pressure or bursting pressure of relief valves and/or safety discs as required in 2.6.1.4 is to be not greater than the design pressure of the system or components given in Table 2.1.4.1.
2.6.1.7 Suitable safety valves are to be provided to the cooling water side of condensers and the brine side of evaporators where the discharge pressure from any cooling water pump or brine circulating pump in the circuit could exceed the design pressure of the piping or any component forming part of the cooling system.

2.6.2 Emergency drainage

2.6.2.1 The R717 systems are to be provided with emergency drain pipes so as to immediately drain off the ammonia overboard in case of accident. Stop valves fitted in such pipes are to be situated outside the refrigerating machinery spaces and to be placed in a sealed box with glass window. The outlets of the drain pipes at the ship's side are to be placed below the light ballast waterline, and are to be provided with non-return valves.

2.6.3 Emergency stopping devices

2.6.3.1 For a refrigerating plant using R717 refrigerant, the prime mover of the compressors is to be provided with an emergency stopping device which is to be situated outside the refrigerating machinery space, and provision is to be made for preventing the inadvertent touching by unauthorized persons.

2.6.4 Alarm buttons in the refrigerated cargo chambers

2.6.4.1 Alarm buttons are to be fitted in the refrigerated cargo holds/chambers for giving alarms to the refrigerating machinery space, engine room and navigation bridge in case of emergency.

CHAPTER 3 REFRIGERATED CARGO HOLDS/CHAMBERS

Section 1 DESIGN OF CARGO HOLDS/CHAMBERS

3.1.1 Airtightness of holds/chambers

3.1.1.1 Each individual hold/chamber is to be of steel construction throughout and hose-tested for tightness, or alternatively, air pressure test may be accepted.

Special consideration will be given to the construction of divisional bulkheads of materials other than steel, between refrigerated cargo holds/chambers, where the holds/chambers concerned are intended for cargo which will not taint or otherwise adversely affect the cargo in any other hold/chamber.

3.1.1.2 Hatch closing appliances, access doors, bilge and manhole plugs are to be made airtight. Where hatch covers or plugs are exposed to ambient conditions, they are to be provided with a double seal.

3.1.1.3 Air ducts and insulation linings are to be so constructed and fitted that moving air is prevented from entering the insulation. Special care is to be taken where cooling pipes, air refreshing ducts, fan supports, etc. protrude through the lining.

3.1.1.4 Refrigeration pipes passing through bulkheads or decks of refrigerated cargo holds/chambers are not to be in direct contact with the steelwork, and the holes through which they pass are to be true and of suitable finish for effectively sealing by the method intended so as to maintain the airtightness of the bulkheads or decks.

The temperature of ship's steelwork close to low temperature refrigeration piping is not to be lower than that acceptable for the steel grade.

3.1.1.5 Where cooling pipes pass through watertight deck plating and bulkheads, the fittings are to be both fire resisting and watertight. Refrigerating pipelines are to be effectively insulated outside the chambers they serve, except within insulated brine coolers and control rooms.

3.1.2 Air circulation

3.1.2.1 When frozen cargo is carried, provision is to be made for adequate circulation of air between the frozen cargo and all the insulation lining surfaces. When cooled cargo of a type which may generate heat or emit gas is carried, provision is to be made for the adequate circulation of air through all the stacks.

3.1.2.2 For the purpose of providing air passage in the refrigerated cargo holds/chambers, cargo battens fastened to or temporary dunnage added during cargo loading to the exposed vertical or near vertical surfaces of the insulation linings may be used. They are to be arranged to suit the air flow.

3.1.2.3 Adequate air flow is to be maintained between cargo and cooling grids, where fitted.

3.1.3 Galvanizing of fixtures

3.1.3.1 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, insulation, meat rail, etc., are to be galvanized.

3.1.4 Oil-impervious coatings of oil tank tops and bulkheads

3.1.4.1 Before insulating the oil tank tops and bulkheads, successive coatings impervious to oil are to be applied. The total thickness of the coating required is to depend on the construction of the tank and the composition of the coating used.

3.1.5 Liquid-tightness

3.1.5.1 Tank top insulation in way of manholes and bilge hats is to be provided with a liquid-tight steel coaming to prevent seepage into the insulation.

Section 2 ACCESSORIES

3.2.1 Temperature measurement instruments in cargo holds/chambers

3.2.1.1 Each refrigerated cargo hold/chamber is to be provided with a suitable number of thermometers, and the exact number and positions of which are subject to approval.

The inside diameter of thermometer tubes is not to be less than 50 mm, and the tubes are not to be in contact with cold decks. Thermometer tubes with their flanges and covers are to be insulated from the deck plating.

Thermometer tubes are to be so arranged on weather decks that water will not run down the tubes when temperatures are being taken.
Where thermometer tubes pass through compartments other than those which they serve, they are to be efficiently insulated.
3.2.1.2 Where electrical remote reading thermometers are adopted for the refrigerated cargo chambers, they are to be fitted in accordance with the relevant requirements in 3.2.2 of this PART. Such thermometers are also to comply with the relevant requirements specified in Chapters 1 and 2, PART SEVEN of the Rules.
3.2.1.3 Where the hold/chamber is intended for the carriage of frozen cargo only, the temperature readings are to be accurate to within ±0.5℃ of the true temperature. Where the hold/chamber is intended for the carriage of fruit, the readings are to be accurate to within +0.2℃ to -0.1℃ of the true temperature in the range -3℃ to +3℃, and to +0.3℃ to -0.2℃ in other parts of the range.
For scale instruments, the scale deflection is to be not less than 5 mm/℃ with division markings enabling the indication to be estimated within 0.1 of a degree.

3.2.2 Installation requirements for remote reading temperature instruments
3.2.2.1 At least two instruments are to be provided for each refrigerating system, with the sensing elements so connected that in the event of a failure of any one instrument, it is to be ensured that other temperature instruments are capable of testing the temperature of each hold/chamber.
Where a data logger is installed and all the sensing elements are connected to this single instrument, at least one sensing element in each hold/chamber or in its circulating air system is to be connected to a separate instrument.
The display of data loggers is to be in digital form or other equally effective visual indication, registering to 0.1 of a degree.
Where the equipment controlling the temperature of the air delivered from the cooler is equipped with a temperature indicator, this indicator will be given consideration as a standby instrument provided that the readings are accurate to within ±0.5℃ of the true temperature.
3.2.2.2 Where galvanometers are fitted, two are to be provided for each indicating instrument and a checking resistance is to be fitted.
3.2.2.3 Where the instruments have individual power supply units, a spare power unit (e.g. transformer and rectifier or battery) is to be provided for each instrument.

3.2.3 CO_2 indication equipment
3.2.3.1 All holds/chambers designed for carriage of fruit in general are to be fitted with permanently installed equipment for indication of CO_2 content.

3.2.4 Sounding, air and drain pipes
3.2.4.1 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0℃ or below, are to be not less than 65 mm bore.
3.2.4.2 Sounding pipes to oil compartments are not to terminate within refrigerated cargo holds/chambers or in the fan and cooler rooms for these holds/chambers, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated cargo holds/chambers or their fan and cooler rooms.

3.2.5 Drainage from refrigerated cargo spaces
3.2.5.1 Provision is to be made for the continuous drainage of the inside of all insulated holds/chambers and cooler trays.
3.2.5.2 Drains which are led from cooler trays situated in the hold/chamber are to be fitted with liquid sealed traps. The inside diameter of drains is not to be less than 38 mm.
3.2.5.3 Where drains from separate holds/chambers join a common main, the branch pipes are each to be provided with a liquid sealed trap.
3.2.5.4 The liquid sealed traps are to be of adequate depth, and arrangements are to be made for ready access to the traps for cleaning and refilling with brine.
3.2.5.5 Screwed plugs or other means for blanking off scuppers draining insulated holds/chambers and cooler trays are not to be fitted. If, however, it is specially desired to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves controlled from readily accessible positions on a deck above the load waterline.
3.2.5.6 Drainage from compartments outside the insulated holds/chambers is not permitted to be led into the bilge of the latter.

Section 3 INSULATION

3.3.1 General requirements

3.3.1.1 All steel bulkheads and shell plating inside the refrigerated cargo holds/chambers are to be covered with insulation material. Metallic lining or other equivalents are to be fitted for the protection of the outer surface of the insulants. Such linings are to be constructed and fitted in accordance with 3.1.1.3 of this Chapter.

3.3.1.2 Insulation linings and air screens, together with supports, are to be strong enough to withstand the loads imposed by either refrigerated or general cargo.

3.3.2 Insulation material

3.3.2.1 The insulants, linings, sealants and paints are not to emit odours which may taint subsequent cargo.

3.3.2.2 The insulants used for the refrigerated cargo holds/chambers are to be suitably resistant to fire and resistant to flame spread. The materials used and their adhesives are to be subject to approval by ISC. If chemical foam type of insulation is proposed, the process is to be subject to approval by ISC and the insulants are to be tested according to the recognized standards (e.g.: GB8624-2012 class B2 and other equivalent standards).

3.3.2.3 The covering on the surface of insulant is to be with the same performance to resist fire and flame spread as that of insulants.

3.3.3 Fitting of insulation material

3.3.3.1 Steelwork is to be thoroughly cleaned and dried, and suitably coated against corrosion before insulation is applied.

3.3.3.2 The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered. Unavoidable crevices are to be filled with insulating material, but bitumen is not to be used for filling crevices.

3.3.3.3 If the cargo to be loaded on to tank top insulation could cause damage to the lining, then additional protection is to be provided in way of the hatch and 0.6 m beyond. The protection may either be of a permanent or temporary nature.

3.3.4 Insulated plugs and panels

3.3.4.1 Insulated removable plugs are to be provided in the insulation where required for easy access to the bilge, bilge suction wells, cooler and chamber drains and tank manhole lids.

Insulated removable panels are to be provided for access to tank air and sounding pipes and drains. If necessary corrosion protection has been considered for the material of air, sounding and drains pipes, insulated removable panels may be dispensed with.

3.3.4.2 Insulation linings, bilge limbers and plugs, hatch covers and plugs and chamber access doors are to be made of water-vapour resisting material, or covered with such material and, where exposed to bilge or external conditions, they are to be sealed.

3.3.5 Insulation of pipes

3.3.5.1 Where the pipes, including scupper pipes, air pipes and sounding pipes, pass through refrigerated holds/chambers intended for temperatures of 0℃ or below, they are to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the steel deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be avoided in so far as practicable.

The air refreshing pipes described in 2.3.11.1 need not, however, be insulated from the steelwork.

3.3.5.2 All pipes passing through the refrigerated cargo chambers mentioned in 3.3.5.1 above are to be well insulated.

CHAPTER 4 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS

Section 1 GENERAL PROVISIONS

4.1.1 Class notation

4.1.1.1 The ships carrying refrigerated containers in cargo holds and complying with the requirements of this Chapter may be assigned the following class notation:

CRC (×× holds), AC f/WC

where: AC — air-cooled refrigerated containers;

f — the simultaneity factor for the refrigerating plant, refer to 4.3.2.3 of this Chapter;

WC — water-cooled refrigerated containers.

4.1.2 Plans and documents

4.1.2.1 The following plans and documents are to be submitted for approval:

(1) Calculations of hold ventilation;

(2) Arrangement of hold ventilation system;

(3) Arrangement of power sockets of refrigerated containers;

(4) Arrangement of hold temperature measuring and monitoring system (where fitted);

(5) Arrangement of refrigerated containers;

(6) Arrangement of safety passageway for personnel.

Section 2 ARRANGEMENT

4.2.1 General requirements

4.2.1.1 A passageway or platform for operators with a width of not less than 2 frames or 1 m, whichever is less, is to be provided on transverse bulkheads at a position corresponding to the height of each tier of containers. Handrail or portable rail is to be fitted at the outside of the passageway for the safety of operators.

4.2.1.2 Where torsion boxes are used as ventilation duct, the size of openings on longitudinal bulkheads is to be minimized as possible so as not to affect the overall longitudinal strength.

4.2.1.3 The deck of the passageway or platform for operators is to be of coarse lattice construction as possible to facilitate air flow.

4.2.2 Arrangement of ventilating equipment

4.2.2.1 In general, the supply fan and air inlet are to be arranged at the fore end of holds and the discharge fan and air outlet at the aft end.

4.2.2.2 The air inlet and outlet on deck are to be located as far apart from each other as is practicable. The height of ventilator coaming above deck is to comply with the relevant requirements of Load Line Convention. Where the ventilator is fitted in the masthouse, openings of a size sufficient for ventilation on both fore and aft end bulkheads are to be considered. Roller blinds are to be fitted on the openings to protect the masthouse from flooding. Suitable drainage means in the masthouse are to be considered for preventing water accumulation.

4.2.2.3 Supply fans or discharge fans may be arranged in holds if necessary.

4.2.2.4 Ventilation ducts are to be arranged as reasonably and uniformly as possible. Air supply ducts are to be extended to the refrigerating units of containers of the lowest tier or the bottom of hold as possible, and air vents are to be provided at each tier of stowed containers as possible. The air vents are to be directly facing the discharge fans of container condensers. The upper and lower air vents are to be spaced according to the general container size. Where stowage of superhigh containers is not specified, the spacing is to be determined according to the standard container size, i.e. approximately 2.5 m.

4.2.2.5 The ventilation duct and air inlet and outlet within a hold are to be evenly arranged as possible so that all spaces of the hold are well ventilated.

4.2.2.6 The ventilating equipment is to be capable of being switched on or off remotely from the bridge where it is to be clearly indicated whether the equipment is switched on or off.

4.2.3 Arrangement of refrigerated containers in hold

4.2.3.1 The distance between the containers and the longitudinal bulkhead is in general not to be less than 250 mm.

4.2.3.2 In case of mixed stacks of refrigerated and non-refrigerated containers, the refrigerated containers are to be stowed at the lower tiers and at both ends of the transverse bulkhead as possible. The refrigerating units of containers are to face the transverse bulkhead.

Section 3 VENTILATION WITHIN HOLDS

4.3.1 General requirements

4.3.1.1 This Section applies to cargo holds carrying refrigerated containers. In addition to the requirements of this Section, the corresponding requirements in this PART are to be complied with.

4.3.1.2 The ventilation of holds carrying refrigerated containers is to be determined mainly according to size, type, number of containers, type of refrigerated cargo to be carried and service area of the ship.

4.3.1.3 The design of ventilation is to comply with the following criteria:

External environment: Air temperature 35℃, relative humidity 70%, seawater temperature 32℃

Temperature in hold: Maximum permissible temperature 45℃.

4.3.2 Air supply required for holds carrying air-cooled refrigerated containers

4.3.2.1 Heat balance calculations are to comply with the following:

(1) The minimum power required for cooling of each refrigerated container:

20 ft 7.5 kW

40 ft 11.0 kW

(2) The effective power loss of supply fan is also to be taken into account.

4.3.2.2 For air supply required in each refrigerated container, the following values are applicable:

20 ft 3,100 m^3/h

40 ft 4,500 m^3/h

4.3.2.3 In general, the simultaneity factor for the refrigerating plant is to be taken as 1. Where the ventilation system of the hold is specially designed for refrigerated containers carrying sharp frozen products, the simultaneity factor may be taken as 0.7 ~ 0.8.

4.3.3 Air supply required for holds carrying water-cooled refrigerated containers

4.3.3.1 Heat balance calculations are to comply with the following:

(1) The minimum power required for cooling of each refrigerated container:

20 ft 1.5 kW

40 ft 2.1 kW

(2) The effective power loss of supply fan is also to be taken into account.

4.3.3.2 For air supply required in each refrigerated container, the following values are applicable:

20 ft 460 m^3/h

40 ft 700 m^3/h

4.3.4 Air inlet and distribution

4.3.4.1 The design of air inlet and distribution is to ensure that refrigerated containers will be effectively cooled under circumstances not related to loading conditions and the occurrence of hot spots is to be avoided. For the design conditions stated in 4.3.2 of this Section, it is recommended that air supply inlets be so arranged and distributed that air flow will directly face the refrigerating units of containers; for the design conditions stated in 4.3.3 of this Section, air supply is to be led into the lowest area in the hold.

4.3.5 Air inlets and outlets on deck

4.3.5.1 The air inlets and outlets of hold ventilation system are to be so arranged as to ensure air supply to refrigerated containers in holds under all weather conditions, and choking of air flow of inlets and outlets is to be avoided.

4.3.6 Bilge arrangement

4.3.6.1 Where the length of the hold carrying refrigerated containers is over 12 m, bilge drainage means are to be arranged both at the fore and aft parts of the hold.

4.3.7 Temperature measuring in holds

4.3.7.1 Temperature measuring devices are to be provided in the holds carrying refrigerated containers, and generally one measuring point each before, after, left of and right of containers above the second tier in each hold.

Section 4 ELECTRICAL INSTALLATIONS

4.4.1 General requirements

4.4.1.1 This Section applies to ships carrying refrigerated box containers in holds and on deck. In addition to the requirements of this Section, the corresponding requirements in PART FOUR of the Rules are to be complied with.

4.4.2 Capacity of power plant

4.4.2.1 Where refrigerated containers are supplied by the main power plant of the ship, the number and capacity of the main generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational condition of propulsion and safety as well as refrigerated containers.

4.4.2.2 For ships adapted to carry refrigerated containers, the containers may be supplied by a leased temporary power plant on deck. If impracticable, standby generating sets are not necessary for power supply of the containers subject to agreement of ISC.

4.4.2.3 For calculation of the capacity of generating sets, see 2.1.1.4 of Chapter 2, PART FOUR of the Rules.

4.4.3 Power distribution for refrigerated containers

4.4.3.1 The sockets of refrigerated containers are to be supplied by special distribution panel which is to be capable of indicating whether the sockets are live and which feeders are electrically connected.

4.4.3.2 The sockets of several containers may be combined to be supplied by one cable, but the connection line of each socket is to be provided with individual short-circuit and overload protection. The common power cable is to be determined according to the total capacity required and the diversity factor specified in 4.4.3.3 of this Section may be used if necessary.

4.4.3.3 Where no exact data are available, the following values may be used as diversity factor for the circuit of container sockets:

20 and less sockets: 0.8;
20 and more sockets: 0.65.

4.4.3.4 The sockets of refrigerated containers are to comply with the standard acceptable to ISC (see ISO 1496-2), and they are to be so fitted as to enable easy use and maintenance.

4.4.3.5 All socket outlets of refrigerated containers are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the ‘on’ position.

4.4.4 Monitoring of refrigerated containers

4.4.4.1 In general, the following conditions of refrigerated containers are to be monitored: FULL COLD, LOW COLD, NULL, DEFROST, HEAT and NO UNIT, actual temperature of air supply and return, set values, etc. The codes of containers for which alarms are initiated may also be monitored.

4.4.4.2 The information on monitoring is generally to be transmitted to the bridge or management center.

4.4.4.3 The automatic monitoring of refrigerated containers may be replaced by manual inspection where practicable.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART SIX FIRE PROTECTION, DETECTION AND EXTINCTION

CONTENTS

Table of Contents

CHAPTER 1 GENERAL 1
Section 1 GENERAL PROVISIONS 1
CHAPTER 2 FIRE EXTINCTION SYSTEMS 3
Section 1 WATER FIRE-EXTINGUISHING SYSTEMS 3
Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS 3
CHAPTER 3 FIRE SAFETY MEASURES 7
Section 1 SAFETY MEASURES FOR DUCT KEELS IN DOUBLE BOTTOM UNDER CARGO OIL TANKS 7
Section 2 FIRE PROTECTION OF MACHINERY SPACES 7
Section 3 PROTECTION OF CARGO PUMP ROOMS ON OIL TANKERS 8
Section 4 MISCELLANEOUS 9
CHAPTER 4 INERT GAS SYSTEMS 14
Section 1 GENERAL PROVISIONS 14
Section 2 INERT GAS SYSTEMS AND NITROGEN GENERATOR SYSTEMS OF DIFFERENT TYPES 14
Section 3 EXAMINATION AND TESTING 15
CHAPTER 5 HELICOPTER FACILITIES 16
Section 1 GENERAL PROVISIONS 16

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 For passenger ships and cargo ships of 500 gross tonnage and upwards engaged on international voyages, the fire detection, fire protection and fire extinction (hereinafter referred to as fire safety) are to comply with the relevant provisions of the International Convention for the Safety of Life at Sea, 1974 (hereinafter referred to as SOLAS Convention) and its amendments, taking into account the requirements of the flag Administration (if any), other than those for personnel qualification, management, operation and maintenance. Ships of less than 500 gross tonnage are to comply with the fire protection requirements of ISC Guidelines for Surveys of Non-convention Ships.

1.1.1.2 The performance standards and test methods for related systems and equipment are to comply with the relevant provisions of the International Code for Fire Safety Systems (hereinafter referred to as FSS Code) and the International Code for Application of Fire Test Procedures (hereinafter referred to as FTP Code).

1.1.1.3 In addition to the above-mentioned requirements, the fire safety of ships engaged on international voyages is to comply with the requirements of this PART.

1.1.1.4 The fire safety of ships engaged on international voyages is also to comply with the requirements, as appropriate, in PART ONE of the Rules.

1.1.1.5 Where necessary, the ship's operator/owner is to pay attention to the standards of other industries and organizations in respect to fire safety of ships. However, such requirements are not conditions for classification with ISC.

1.1.2 Plans and documents

1.1.2.1 The following plans and documents are to be submitted for approval:

(1) Details of fire division plan and fire protection typical nodes;

(2) Arrangement of fire insulation, arrangement of deck covering and arrangement of fire doors;

(3) Arrangement of ventilation system (including fire dampers and smoke dampers, if applicable);

(4) Arrangement of fixed fire extinguishing systems (including the fire extinguishing system for scavenge spaces of crosshead type diesel engines) together with extinguishing medium calculations;

(5) Arrangement of water fire-extinguishing systems;

(6) Arrangement of local water-based fixed fire-extinguishing systems and calculations (if applicable);

(7) Arrangement of fixed fire detection and fire alarm systems;

(8) Diagram of control system of quick-closing valve of fuel and lub. oil tanks;

(9) Fire control plan;

(10) Arrangement of inert gas systems (if applicable);

(11) Arrangement of oxygen and acetylene bottle including pipes (if applicable);

(12) Arrangement of liquefied petroleum gas cooking ranges and gas bottles including pipes (if applicable);

(13) Arrangement of oil-fired cooking ranges including pipes (if applicable);

(14) Arrangement of fire-extinguishing means for paint lockers and store rooms containing flammable liquids (if applicable);

(15) Arrangement of fire-extinguishing system of deep-fat cooking equipment (if applicable);

(16) Other plans and documents as deemed necessary by ISC.

1.1.2.2 The following plans and documents are to be submitted for information:

(1) Instruction manual or operating manual of the inert gas systems required by Chapter 15 of FSS Code.

1.1.3 Products certificate

1.1.3.1 The principal materials, equipment and installations used for the fire safety of ships are all to be provided with ISC appropriate products certificate, as detailed in Appendix 1B — List of Certification Requirements for Statutory Marine Products of Chapter 3, PART ONE of the Rules.

1.1.4 Basic requirements for arrangement of fire stations and systems

1.1.4.1 Any fixed fire-extinguishing systems and their stations, fire pumps, fire-extinguishing medium containers as well as other arrangements on board passenger ships are not to be arranged forward of the collision bulkhead.

1.1.4.2 Stations or centralized distribution manifolds for all fixed fire-extinguishing systems and their power sources are to be located in easily accessible positions and are not likely to be cut off by a fire in the spaces protected.
1.1.4.3 All fixed fire-extinguishing systems and their stations are to be clearly marked and the walkways leading to the stations are to be kept clear.

1.1.5 Fire safety measures for ships

1.1.5.1 The fire safety measures for tugs are to be dealt with as those for cargo ships of equivalent tonnage; the fire safety measures for ice-breakers, salvage ships and self-propelled working ships (such as dredges, floating cranes and other working ships etc.) are to be dealt with in accordance with the relevant requirements of the Code of Safety for Special Purpose Ships (resolution MSC.266(84)).
1.1.5.2 The fire safety of special purpose ships are to comply with the requirements in the Code of Safety for Special Purpose Ships, 2008, adopted by the International Maritime Organization by resolution MSC.266(84).
1.1.5.3 For non-propelled ships, the fire safety measures are to be provided by making reference to the relevant provisions in this PART according to the ship types and purposes.
1.1.5.4 Tankers carrying products having a flash point exceeding 60℃ (closed-cup test) are to be dealt with as cargo ships of equivalent tonnage, in addition to complying with the following requirements:
(1) Isolation valves are to be fitted in the fire main of the water fire-extinguishing system at the poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.
(2) Four fire-fighter's outfits are to be provided.
(3) In lieu of the fixed fire-extinguishing system for tanks, they are to be fitted with a fixed deck foam system complying with requirements.
1.1.5.5 Unless expressly provided otherwise, for the purpose of this PART, oil tankers mean tankers carrying crude oil or petroleum products having a flash point not exceeding 60℃ (closed-cup test), as determined by an approved flash point apparatus, and a Reid vapour pressure which is below the atmospheric pressure. Other tankers carrying liquids having the same fire hazard, e.g. liquefied gas carriers and chemical tankers, are also to comply with the requirements of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as appropriate.

1.1.6 Acceptance of substitutes

1.1.6.1 Where in this PART any particular type of appliances, apparatus, extinguishing media or arrangements is specified for any ship, any other type of appliance etc., not less effective may be allowed, provided the relevant calculations and test or application information are provided.

1.1.7 Miscellaneous

1.1.7.1 The arrangement of fuel oil, lubricating oil and other flammable oils is to be in compliance with the relevant requirements of Chapter 4, PART THREE of the Rules.
1.1.7.2 Unless expressly specified in this PART, the machinery, piping and pressure vessels used in fire safety systems are also to be in compliance with the relevant requirements of PART THREE of the Rules.
1.1.7.3 In addition to complying with the requirements of this PART, the electrical equipment and electronic devices in fire detection systems and other detection and alarm systems used for periodically unattended machinery spaces are to be in compliance with the relevant requirements of PART SEVEN of the Rules.
1.1.7.4 In addition to complying with the requirements of this PART, the electrical equipment and electronic devices used in fire safety systems are to be in compliance with the relevant requirements of PART FOUR of the Rules.
1.1.7.5 Fire extinguishing appliances are to be kept in good order and available for immediate use at all times.

CHAPTER 2 FIRE EXTINCTION SYSTEMS

Section 1 WATER FIRE-EXTINGUISHING SYSTEMS

2.1.1 Capacity of fire pumps

2.1.1.1 Where the water fire-extinguishing system is used for a deck foam system in tankers, the capacity of the fire pumps is to be sufficient to satisfy the requirements for operation of the deck foam system at its required output and the simultaneous use of two water jets with a throw of 12 m at the required pressure from the fire main.

2.1.2 Number and arrangement of fire pumps

2.1.2.1 Cargo ships are to be provided with fire pumps according to the following:

(1) in cargo ships of 500 gross tonnage and upwards but less than 1,000 gross tonnage, at least two power pumps are to be provided, one of which is to be an independent pump;

(2) in cargo ships of less than 500 gross tonnage, at least one independently driven fire pump is to be provided.

2.1.2.2 The arrangement of emergency fire pump is to comply with the requirements of Chapter 12 of the International Code for Fire Safety Systems (FSS Code).

2.1.3 Internal **diameter and pressure of fire main**

2.1.3.1 In general, the internal diameter of the fire main is not to be less than that required in the following formula:

$$d = \frac{L}{1.2} + 25 \quad \text{mm}$$

where: d — internal diameter of the fire main, in mm, but need not exceed 125 mm for cargo ships (except for ships designed to carry five and more tiers of containers on or above the weather deck) and 180 mm for passenger ships and in no case to be less than 50 mm;

L — length of ship measured between perpendiculars, in m.

2.1.3.2 In cargo ships of less than 1,000 gross tonnage, with the two pumps simultaneously delivering water through the specified nozzles, through any adjacent hydrants, a minimum pressure of 0.25 N/mm^2 is to be maintained at all hydrants.

Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS

2.2.1 General requirements

2.2.1.1 Means are to be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for not less than 20 s before the medium is released.

Where automatic audible alarms are fitted to warn of the release of fire-extinguishing medium into cargo pump rooms onboard tankers carrying crude oil or petroleum products having a flash point not exceeding 60℃ (closed-cup test), they may be of the pneumatic type or electric type:

(1) if pneumatically operated, in cases where the periodic testing of such alarms is required, CO_2-operated alarms should not be used owing to the possibility of the generation of static electricity in the CO_2 cloud; air operated alarms may be used provided the air supply is clean and dry.

(2) if electrically operated, the alarms are to satisfy the requirements of Section 16, Chapter 2, PART FOUR of the Rules and the arrangements are to be such that the electrical actuating mechanism is located outside the cargo pump room, except where the alarms are certified intrinsically safe.

2.2.1.2 At each location of the means of control of any fixed gas fire-extinguishing system, there is to be sufficient illumination including emergency lights in addition to the main lights.

2.2.1.3 Storage rooms of extinguishing medium used for all fixed gas fire-extinguishing systems are to comply with the following requirements:

(1) Storage rooms of extinguishing medium are to be used only for the storage of containers and other components and parts of the systems.

(2) Storage rooms of extinguishing medium are to be provided with direct communications to the bridge or control station.

(3) The key to the storage rooms of extinguishing medium is to be stowed in a box with glass cover which is to be situated in an easily accessible and conspicuous position near the door.
(4) In each storage room of extinguishing medium there is to be displayed a clear and permanent schematic diagram showing the arrangement of the containers, manifold, piping and fittings relating to the release of extinguishing medium, together with the concise instructions for the operation of the system.
2.2.1.4 The release and alarm of the fixed gas fire-extinguishing system for the protection of machinery spaces, including the opening of the release box door for the purpose of test, is not to have automatic linkage with the system that shuts down the ventilation fans and oil pumps in machinery spaces.

2.2.2 High-pressure carbon dioxide systems

2.2.2.1 For cargo spaces the quantity of carbon dioxide available is, unless otherwise provided, to be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space so protected in the ship.
2.2.2.2 For machinery spaces the quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:
(1) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
(2) 35% of the gross volume of the largest machinery space protected, including the casing.
Provided that the above-mentioned percentages may be reduced to 35% and 30% respectively for cargo ships of less than 2,000 gross tonnage; provided also that if two or more machinery spaces are not entirely separate they are to be considered as forming one space.
2.2.2.3 Where the volume of free air contained in air receivers in any space is such that, if released in such space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium is to be provided. In general, for the space (e.g. engine room) fitted with starting air receivers, the effect upon free air volume in the air receivers is to be taken into account, when calculating CO_2. Or, if compressed air in the air receivers can be discharged into open space located outside the engine room through safe valves and its conducting pipes, the effect upon air receivers is not to be taken into account, when calculating CO_2.
2.2.2.4 When carbon dioxide is used as an extinguishing medium for the cargo pump room in tankers carrying cargo oil having a flash point not exceeding 60℃, the quantity of carbon dioxide is to be sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the cargo pump room including the casing. For tankers carrying cargo oil having a flash point exceeding 60℃, if the cargo pump room is located in a separate space, it is to be treated as a machinery space.
2.2.2.5 For ro-ro spaces and vehicle spaces, other than special category spaces, which are capable of being sealed from a location outside the spaces, if a carbon dioxide system is fitted, the quantity of gas available is to be at least sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space which is capable of being sealed.
2.2.2.6 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0.56 m^3/kg.
2.2.2.7 Piping of carbon dioxide is to comply with the following requirements:
(1) Each connecting pipe led from each bottle head valve to the collecting pipe is to be provided with a non-return valve.
(2) The manifold connecting the collecting pipes and distribution manifold is to be provided with a pressure gauge having a maximum range of 1.5 times the working pressure.
(3) For machinery spaces of Category A or cargo pump rooms, the piping is to be provided with sufficient number and adequate size of nozzles so that 85% of carbon dioxide can be discharged into the space within 2 min. Approximately 10% of the total quantity of CO_2 is to be discharged to the protected space below the floor in engine room. For vehicle spaces and ro-ro spaces which are not special category spaces, the arrangements are to be such as to ensure that at least two thirds of the gas required for the relevant space are introduced within 10 min. For container and general cargo spaces (primarily intended to carry a variety of cargoes separately secured or packed) the fixed piping system is to be such that at least two thirds of the gas can be discharged into the space within 10 min. For solid bulk cargo spaces the fixed piping system is to be such that at least two thirds of the gas can be discharged into the space within 20 min. The system controls are to be arranged to allow one third, two thirds and the entire quantity of gas to be discharged based on the loading condition of the hold.
(4) The diameter of carbon dioxide piping leading to the spaces as stated in 2.2.2.7(3) above is to be determined by calculation in accordance with the expected quantity to be conveyed through the piping

based on the recognized standard①.The diameter of carbon dioxide piping in machinery spaces of category A and cargo pump rooms may also be determined from Table 2.2.2.7(4). The maximum quantities of carbon dioxide conveyed by the corresponding pipe diameters are given in Table 2.2.2.7(4).

Internal Diameter of Pipes and Conveyed Quantity Table 2.2.2.7(4)

Maximum quantity of carbon dioxide conveyed by the pipe (kg)	Internal diameter of pipe (mm)
60	15
100	20
135	25
275	32
500	40
1100	50
1600	65
2400	80
3300	90
4750	100
6800	114
9500	127
15250	152

(5) The minimum wall thickness of CO_2 pipes is given in Table 2.2.2.7(5). Slight difference from the thickness listed in the Table will be accepted for the purpose of selecting standard pipes.

Minimum Wall Thickness of CO_2 Pipes Table 2.2.2.7(5)

External diameter of pipe (mm)	Wall thickness (mm)	
	Piping forward of distribution manifold	Piping from distribution manifold to protected space (nozzles)
21.3 ~ 26.9	3.2	2.6
30.0 ~ 48.3	4.0	3.2
51.0 ~ 60.3	4.5	3.6
63.5 ~ 76.1	5.0	3.6
82.5 ~ 88.9	5.6	4.0
101.6	6.3	4.0
108.0 ~ 114.3	7.1	4.5
127.0	8.0	4.5
133.0 ~ 139.7	8.0	5.0
152.4 ~ 168.3	8.8	5.6

Notes:
1. Pipes are to be galvanized at least inside, except those fitted in the engine room where galvanizing may not be required.
2. For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.
3. The external diameters and thicknesses have been selected from ISO Recommendations R336 for smooth welded and seamless steel pipes. Diameter and thickness according to other national or international standards may be accepted.
4. For larger diameters the minimum wall thickness will be subject to special consideration.
5. In general the minimum thickness is the nominal wall thickness and no allowance need be made for negative tolerance or reduction in thickness due to bending.

(6) Distribution piping leading to cargo spaces is to have a bore of not less than 20 mm, and those leading to the nozzles are to have a bore of not less than 15 mm.

(7) CO_2 piping is to be provided with compressed air cleaning connections at its manifold or distribution manifold.

(8) CO_2 pipes are to be of seamless steel, except that flexible metallic pipes can be used as the connecting pipe led from each bottle head valve to the collecting pipe in accordance with recognized standards.

(9) For closed ro-ro cargo spaces, the piping arrangements are to be such that 2/3 of the gas required for a particular space can be discharged into the space within 10 min.

2.2.2.8 Carbon dioxide bottles are to comply with the following requirements:

(1) CO_2 bottles are to be of seamless steel. Each bottle is to be furnished with a certificate and to have on its body clear and permanent identification of weight, capacity, hydraulic test pressure, date of test, manufacturer' serial number and also inspection stamp.

(2) The bottles are to be wholly painted in bright colour but white in way of the markings, and with letters of "carbon dioxide (or CO_2)".

(3) The charging ratio for CO_2 bottles is to be suitable for the strength of the bottles and generally not to be more than 0.67 kg/L.

①E.g. Code of Design for Carbon Dioxide Fire Extinguishing System (GB50193-93(2010 edition)) or Fire Protection Equipment – Carbon Dioxide Extinguishing Systems for Use on Premises – Design and Installation (ISO 6183-2022), etc.

(4) Bottle head valves are to be associated with a steel or copper seamless tube having a diameter of 10 to 12 mm snipped off at its lower end and terminated near the bottom of the bottle.
(5) Bottle head valves are to be provided with safety diaphragms or other approved safety devices. The bursting pressure of the safety diaphragms is to be 18.6 ±1 MPa. For other approved safety devices, the relevant technical and test data are to be provided with, to demonstrate that the escape gas is ensured to be capable of being released when the bursting pressure reaches the same as above.
After bursting of safety diaphragms, the escape gas from bottle head valves is to be led to the open atmosphere through suitable piping. However, where the storage room for CO_2 cylinders is fitted with a dedicated mechanical ventilation system capable of providing at least 6 air changes per hour and keeping temperature in the room below 45°C and provided with a temperature alarm, such piping may be dispensed with.
(6) Bottles head valves are to be made of forged bronze or other suitable materials.
(7) CO_2 bottles are to be divided into groups according to the required quantity for different spaces to be protected. If releasing of the carbon dioxide is hand-operated directly by mechanical means, the number of bottles in each group is not to exceed 12.
2.2.2.9 Testing of carbon dioxide systems
(1) CO_2 bottles and bottle head valves are to be subjected to a hydraulic test of 24.5 MPa. Safety diaphragms are to be burst-tested in accordance with 2.2.2.8(5) by selecting 10% at random.
(2) On completion of fitting the bottle head valves, CO_2 bottles are to be subjected to an air-tightness test in the workshop to a pressure equal to the design pressure of the bottle.
(3) The pipes and valves of CO_2 piping systems are to be subjected to a hydraulic test with a pressure of at least 11.8 MPa for the distribution manifold and control valves and for pipe lengths between bottle head valves and the distribution manifold, and 1.0 MPa for pipe lengths between the distribution manifold and nozzles. The above tests may be carried out in workshop. On completion of the hydraulic test, CO_2 piping is to be subjected to an airtightness test using compressed air on board the ship to at least 0.69 MPa with the ends closed for checking the tightness of each connection.
(4) On completion of installation on board, the CO_2 piping system is to be function-tested with a pneumatic pressure not less than 2.47 MPa for checking the operation of releasing mechanism.

2.2.3 Low-pressure carbon dioxide systems

2.2.3.1 Where a low-pressure CO_2 system is fitted, the piping system is to be designed in such a way that the CO_2 pressure at the nozzles should not be less than $1N/mm^2$.

CHAPTER 3 FIRE SAFETY MEASURES

Section 1 SAFETY MEASURES FOR DUCT KEELS IN DOUBLE BOTTOM UNDER CARGO OIL TANKS

3.1.1 Safety aspects of double bottoms and duct keels under cargo oil tanks (corresponding to SOLAS regulation II-2/4.5.2.4)

3.1.1.1 Pipe ducts in the double bottom are to comply with the following requirements:

(1) They are not to communicate with the engine room.

(2) Provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.

(3) In the duct, provision is to be made for adequate mechanical ventilation.

Section 2 FIRE PROTECTION OF MACHINERY SPACES

3.2.1 Measures to prevent the spills of oil fuel, lubricating oil, hydraulic oil, thermal oil and other combustible liquids

3.2.1.1 Tanks (corresponding to SOLAS regulation II-2/4.2.2.4)

(1) Air pipes from fuel oil tanks are to be led to a safe position on the open deck.

Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

(2) Any overflow pipe is to have a sectional area of at least 1.25 times that of the filling pipe and is to be led to an overflow tank of adequate capacity or to a storage tank having space reserved for overflow purposes.

An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight glass with good illumination is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight glasses are to be placed on vertical pipes only and in readily visible positions.

3.2.1.2 Oil fuel gauge (corresponding to SOLAS regulation II-2/4.2.2.3.5.1 and 4.2.2.3)

(1) Short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge, provided an overflow system is fitted.

(2) Level switches may be used below the tank top provided they are contained in a steel enclosure or other enclosures not capable of being destroyed by fire.

3.2.1.3 Pump control (corresponding to SOLAS regulation II-2/5.2.2.3)

Controls of the oil pumps (e.g. oil transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators) required by Regulation II-2/5.2.2.3 of SOLAS are also to be provided from the compartment itself.

3.2.1.4 Oil fuel pipelines (corresponding to SOLAS regulation II-2/4.2.2.5.1)

Hose clamps and similar types of attachments for flexible pipes are not to be permitted.

3.2.1.5 Arrangements of oil fuel (corresponding to SOLAS regulation II-2/4.2.2 and 4.2.5.2)

Oil fuel in storage tanks is not to be heated to temperature within 10℃ below the flash point of the oil fuel, except that where oil fuel in service tanks, settling tanks and any other tanks in supply system is heated the following arrangements are to be provided:

(1) the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to below 60℃, or the outlet of the vent pipes is located 3 m away from a source of ignition;

(2) the vent pipes are fitted with flame screens;

(3) there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable);

(4) enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams;

(5) electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

Section 3 PROTECTION OF CARGO PUMP ROOMS ON OIL TANKERS

3.3.1 Measures to prevent explosions in cargo pump rooms on oil tankers

3.3.1.1 The requirements of 3.3.1.2 to 3.3.1.5 below apply to the cargo pump rooms of oil tankers where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided. Pump rooms intended solely for ballast or oil fuel transfer, however, need not comply with these requirements.

3.3.1.2 Cargo pumps, ballast pumps and stripping pumps, installed in cargo pump rooms and driven by shafts passing through cargo pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands, bearings and pump casings. These devices are to be capable of automatically effecting a continuous audible and visual alarm in the cargo control room or the pump control station.

3.3.1.3 Lighting in cargo pump rooms, except emergency lighting, is to be interlocked with ventilation such that the ventilation has been in operation for at least 5 min before switching on the lighting. Failure of the ventilation system is not to cause the lighting to go out.

3.3.1.4 A system for continuously monitoring the concentration of hydrocarbon gases is to be fitted. Sampling points or detector heads are to be located in suitable positions in order that potentially dangerous leakages are readily detected. When the hydrocarbon gas concentration reaches a preset level, which is not to be higher than 10% of the lower flammable limit, a continuous audible and visual alarm signal is to be automatically effected in the cargo pump room, engine control room, cargo control room and navigation bridge to alert personnel to the potential hazard.

(1) Where a system for sequential sampling is used for sampling of cargo pump rooms including exhaust ducts, the time between two samplings of a same position is to be reasonably short.

(2) For the number and arrangement of sampling points, appropriate consideration is to be given to the vapour density of carried cargo and the ventilation condition of tanks.

3.3.1.5 All cargo pump rooms are to be provided with bilge level monitoring devices together with appropriately located alarms. Bilge high-level alarms are acceptable as an alternative means for the level monitoring devices.

3.3.2 Gland seals in cargo pump room bulkheads

3.3.2.1 Where drive shafts pass through cargo pump room bulkhead or deck plating, gastight glands are to be fitted. The glands are to be efficiently lubricated from outside the cargo pump room.

3.3.2.2 The seal parts of the glands are to be of material that will not initiate sparks. The glands are to be constructed and fitted in accordance with the relevant requirements for fittings attached to watertight bulkheads, and if a bellows piece is incorporated in the design, it is to be pressure tested before fitting.

3.3.3 Cargo pump room ventilation

3.3.3.1 With the following arrangement of exhaust trunking there are to be 20 air changes per hour on the total volume of the cargo pump room:

(1) In the cargo pump room bilges just above the transverse floor plates on bottom longitudinals, so that air can flow over the top from adjacent spaces.

(2) The ventilator inlet of the cargo pump room is to be close to the bottom so far as practicable and above floors or bottom longitudinals. An emergency intake is to be fitted about 2 m above the cargo pump room lower grating (This emergency intake would be used when the lower intakes are sealed off due to flooding in the bilges.). The emergency intake is to have a damper fitted which is capable of being opened or closed from the exposed main deck and cargo pump room lower grating level.

(3) The foregoing exhaust system is in association with open grating floor plates to allow the free flow of air.

(4) A grating damper may be used between upper emergency and lower main ventilator openings, which can be shown to result in at least the required 20 air changes per hour through the lower inlets, can be adopted without the use of dampers. When the lower access inlets are closed, then at least 15 air changes per hour are to be obtained through the upper inlets.

3.3.4 Temperature of steam and heating media within the cargo area

3.3.4.1 On oil tankers, the steam and heating media temperature within the cargo area is not to exceed 220℃.

3.3.4.2 On gas carriers and chemical tankers, the maximum temperature is to be adjusted to take into account the temperature class of the cargoes.

3.3.5 Non-sparking fans

3.3.5.1 A fan is considered as non-sparking if in either normal or abnormal conditions it is unlikely to produce sparks.

3.3.5.2 Design criteria

(1) The air gap between the impeller and the casing is not to be less than 0.1 times the shaft diameter in way of the impeller bearing but not less than 2 mm. It need not be more than 13 mm.

(2) Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation openings on the open deck to prevent the entrance of objects into the fan housing.

3.3.5.3 Materials

(1) The impeller and the housing in way of the impeller are to be made of alloys which are recognized as being spark-proof by appropriate test.

(2) Electrostatic charges both in the rotating body and the casing are to be prevented by the use of anti-static materials. Furthermore, the installation on board of the ventilation units is to be such as to ensure the safe bonding to the hull of the units themselves.

(3) Tests may not be required for fans having the following combinations:

① impellers and/or housings of nonmetallic material, due regard being paid to the elimination of static electricity;

② impellers and housings of non-ferrous materials;

③ impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller;

④ any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

(4) The following impellers and housings are considered as sparking and are not permitted:

① impellers of an aluminium alloy or magnesium alloy and a ferrous housing, regardless of tip clearance;

② housing made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance;

③ any combination of ferrous impellers and housings with less than 13 mm design tip clearance.

(5) Type tests on the finished product are to be carried out in accordance with the requirements of ISC or an equivalent national or international standard acceptable to ISC.

Section 4 MISCELLANEOUS

3.4.1 Aluminium coatings on board oil tankers and chemical tankers

3.4.1.1 The use of aluminium coatings containing greater than 10 percent aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, cargo pump rooms, cofferdams or any other area where cargo vapour may accumulate.

3.4.1.2 Aluminized pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

3.4.2 Tank cleaning openings

3.4.2.1 Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

3.4.3 Portable instruments for measuring oxygen and flammable vapour concentrations

3.4.3.1 Every oil tanker is to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable O_2 analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

3.4.3.2 In addition to the requirement in 3.4.3.1, for tankers fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere (% gas by volume).

3.4.4 Pressurization of cargo tanks

3.4.4.1 PV valves to oil tanks are not to be set at pressures in excess of 0.021 MPa unless the tank scantlings have been specially considered.

3.4.5 Reinforced thickness of ballast and cargo oil piping

3.4.5.1 Ballast piping passing through cargo tanks and cargo oil pipes passing through segregated ballast tanks, as defined by regulation 19.3.6 of MARPOL Annex I, are to comply with the following requirements:
(1) The pipes are to be of heavy gauge steel of minimum wall thickness according to Table 3.4.5.1 hereunder with welded or heavy flanged joints the number of which is to be kept to a minimum.
(2) Expansion bends only (not glands) are permitted in these lines within cargo tanks for serving the ballast tanks and within the ballast tanks for serving the cargo tanks.

Minimum Wall Thickness of Pipes **Table 3.4.5.1**

Nominal diameter (mm)	Minimum wall thickness (mm)
50	6.3
100	8.6
125	9.5
150	11.0
200 and above	12.5

3.4.5.2 The thicknesses shown in Table 3.4.5.1 refer to carbon steel pipes.
3.4.5.3 Connection between cargo piping and ballast piping referred to above is not permitted except for emergency discharge as specified in the Unified Interpretation to regulation 1.18 of MARPOL Annex I. Nevertheless, provision may be made for emergency discharge of the segregated ballast by means of a connection to a cargo pump through a portable spool piece. In this case non-return valves are to be fitted on the segregated ballast connections to prevent the passage of oil to the ballast tanks. The portable spool piece is to be mounted in a conspicuous position in the cargo pump room and a permanent notice restricting its use is to be prominently displayed adjacent to it.
Shut-off valves are to be provided to shut off the cargo and ballast lines before the spool piece is removed.
3.4.5.4 The ballast pump is to be located in the cargo pump room, or a similar space within the cargo area not containing any source of ignition.

3.4.6 Bow and stern loading and unloading arrangements on oil tankers

3.4.6.1 Where a cargo hose connection is arranged outside the cargo tank area, the pipe leading to such connections is to be provided with means of segregation such as a spectacle flange, removable spool piece or equivalent① located within the cargo area. The space within 3 m of the manifold is to be considered as a dangerous area with regard to electrical or incendive equipment.

3.4.7 Direct loading pipes to oil tanker cargo tanks

3.4.7.1 In order to avoid the generation of static electricity when cargo is loaded direct into tanks, the loading pipes are to be led as low as practicable in the tank.

3.4.8 Cargo openings in the bottoms of topside tanks of ships carrying alternatively oil and grain

3.4.8.1 This requirement applies to ships carrying alternatively oil having a flash point not exceeding 60℃ or other cargoes.
When ships are designed to transport alternatively oil or dry cargoes, openings which may be used for cargo operations are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless alternative approved means are provided to ensure equivalent integrity.

3.4.9 Emergency fire pumps in cargo ships②

3.4.9.1 In cargo ships, the room(s) where the pump and prime mover are installed is/are to have adequate space for maintenance work and inspections.

3.4.10 Prohibition of carriage in fore peak tanks of oil or other liquid substances which are flammable

3.4.10.1 In ships of 400 gross tonnage and above, compartments forward of the collision bulkhead are not

---

① Refer to IMO MSC/Circ.474.

② Emergency fire pumps in cargo ships are to additionally comply with the requirements of SOLAS regulation II-2/10 and Chapter 12 of FSS Code, as appropriate.

to be arranged for the carriage of oil or other liquid substances which are flammable.

3.4.11 Sea intakes for fire pump on ships with ICE Class

3.4.11.1 On ships with ICE Class at least one of the fire pumps is to be connected to a sea chest which is provided with de-icing arrangements.

3.4.12 Installation requirements for analysing units for continuous monitoring of flammable vapours

3.4.12.1 This requirement applies to gas analysing units of the sampling type located outside gas dangerous zones and fitted on board gas carriers or on board oil/chemical tankers.

3.4.12.2 Gas analysing units with non-explosion proof measuring equipment may be located in areas outside cargo areas, e.g. in cargo control room, navigation bridge or engine room when mounted on the forward bulkhead provided the following requirements are observed:

(1) Sampling lines are not to run through gas safe spaces, except where permitted under (5).

(2) The gas sampling pipes are to be equipped with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location.

(3) Bulkhead penetrations of sample pipes between safe and dangerous areas are to be of approved type and have same fire integrity as the division penetrated. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead on the gas safe side.

(4) The gas detection equipment including sample piping, sample pumps, solenoids, analysing units etc. is to be located in a reasonably gastight enclosure (e.g. a fully enclosed steel cabinet with a gasketed door) which is to be monitored by its own sampling point. At gas concentrations above 30% LFL inside the enclosure the entire gas analysing unit is to be automatically shut down.

(5) Where the enclosure cannot be arranged directly on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units, and are to be routed on their shortest ways.

3.4.13 Fore peak ballast system on oil tankers

3.4.13.1 The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided:

(1) the fore peak tank is considered as hazardous;

(2) the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be determined according to the hazardous zones defined in paragraphs 4.2.2.9 and 4.2.3.1 of IEC 60092-502: Electrical installations in ships - Tankers - Special features;

(3) means are provided, on the open deck, to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument;

(4) the sounding arrangement to the fore peak tank is direct from open deck;

(5) the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:

① in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after it has been proven to be gas free; or any electrical equipment which is not certified safe in the enclosed space is isolated;

② in case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space can be well ventilated.

3.4.14 Arrangement of oxygen, acetylene cylinders

3.4.14.1 Storage of oxygen, acetylene cylinders is to meet the following requirements:

(1) The design, construction and approval of gas cylinders are to comply with the applicable requirements of PART THREE of the Rules or requirements of the recognized standards. Oxygen cylinders are to be provided with proper pressure relief device such as a fusible plug or a rupture disc.

(2) Pipes, pipe fittings, pipe joints and valves are to comply with the requirements of Class I piping systems. Materials for acetylene on the high-pressure side between the cylinders and the regulator are to be steel. Copper or copper alloys containing more than 65% copper are not to be used in the whole fixed acetylene piping. Materials for oxygen piping are to be of steel or copper. Materials for both oxygen and acetylene systems are to be corrosion resistant, all the pipes of the fixed piping are to be seamless drawn.

(3) The connections between fixed pipe sections are to be carried out by means of butt welding. Other types

of connections including threaded connections and flange connections are not permitted.
(4) Where there are two or more cylinders of each gas, separate dedicated storage rooms are to be provided for each gas.
(5) Storage rooms are to be constructed of steel, not located below the open deck, and be well ventilated and accessible from the open deck. The ventilation arrangement is to be separate from the ship's ventilation systems.
(6) Possible sources of ignition are not to be fitted in acetylene storage room and any electrical installation, if fitted, is to be of a certified explosion-proof type.
(7) Securing arrangements of gas cylinders are to be released easily and quickly for the expeditious removal of cylinders in the event of fire.
(8) Prominent and permanent "NO SMOKING" signs are to be displayed at the gas cylinder storage room.
(9) Where cylinders are stowed in open locations means are to be provided to:

① protect cylinders and associated piping from physical damage;

② minimize the likelihood of exposure to hydrocarbons;

③ ensure suitable drainage.

(10) If the pipes connecting the work station for oxyacetylene welding and gas storage room need to pass through deck or bulkhead, fixed pipes are to be provided between gas cylinder and work station for welding and they are not to pass through accommodation spaces, service spaces and control stations. Suitable protection is to be provided at the position passing through deck or bulkhead. Outlet stations of fixed pipes are to be fitted with shut-off valves.

3.4.15 Arrangement of liquefied-gas-fired ranges

3.4.15.1 If liquefied-gas-fired ranges are fitted in a galley, the following requirements are to be met:
(1) Ranges, gas cylinders, angle valves and pressure reduction valves, etc. are to be designed, manufactured and tested in accordance with applicable standards and codes.
(2) Unless separated from adjacent spaces by suitable fire division, the galley is to be situated above the main deck. Inside the galley no opening or stairway leading to the spaces below is allowed; or where an opening is arranged, a positive means of closing is to be provided.
(3) Liquefied gas ranges are to be fitted securely at predetermined positions. Means are to be provided to prevent shifting of ranges.
(4) Liquefied gas cylinders are to be positioned vertically and fixed securely. Fixed hoops are to be capable of being released easily and quickly. Cylinders are to be provided with wood blocks under the bottom to avoid impact.
(5) Steel liquefied gas pipe lengths are to be connected by welding. Threaded joints may be adopted for connecting ranges, valves, instrumentation etc. with pipes and valves. The joints are to be fitted with oil-resistant sealing washers or coated with binder to ensure gastightness.
The joints between rubber hoses and pressure reduction valves, ranges or steel pipes are to be cramped by metal clamps. The clamps are to be connected securely. They are to be capable of being easily fitted or removed and to ensure gastightness.
(6) For the pressure of strength test and tightness test on liquefied gas piping system, the requirements given in Table 3.4.15.1 are to be complied with.

Test Pressure of Piping **Table 3.4.15.1**

Liquefied gas piping	Test pressure	
	Strength test (in workshop) (MPa)	Tightness test (after installation on board) (MPa)
Piping from cylinder to pressure reduction valve	2.4	2.0
Piping from pressure reduction valve to range	0.2	0.1

(7) Storage spaces containing liquefied gas cylinders are to comply with the requirements of 3.4.14 of this Section and the fire safety requirements of 3.4.17 of this Section.
3.4.15.2 For galleys where oil or flammable gas is in use, their structure and arrangement are to comply with the following requirements:
(1) The oil fuel tank is to be located outside the galley and is to be fitted with approved means of filling and venting.
(2) The oil fuel or flammable gas supply to the burners is to be capable of being cut off from a readily accessible position outside the galley in the event of a fire occurring in the galley.

(3) Naked fire is not to be in use for ignition of oil fuel or flammable gas, except for galley stoves or water heaters. All pipelines for delivering oil fuel or flammable gas from containers to the stoves or water heaters are to be of steel or other approved materials. And safety appliances for automatic shutoff are to be provided so that they will automatically shut off oil fuel and flammable gas supply when the flame in the stoves goes out.
(4) Naked fire is not to be in use for warming oneself. Galley stoves and similar appliances are to be firmly fixed at their design positions, and means are to be provided to prevent them from shifting. Sufficient fire protection and insulation layers are to be provided under, around and over. The possibility of blocking up by combustion remains is to be kept to a minimum and cleaning tools are to be provided. Where the damper for limitation of the exhaust in the uptake is in a closed position, sufficient flow area is to be kept. The ventilator in way of the stove space is to be of sufficient cross-sectional area so as to supply the stoves with enough air for full combustion.
(5) Galleys are to be provided with ventilation appliances of sufficient capacity so as to purge the smoke and the gas liable to escape to a safe place.

3.4.16 Provision of fire extinguishers

3.4.16.1 In passenger ships, at least two portable fire extinguishers for each main vertical zone or enclosed space divided by watertight bulkheads, and for each floor of passenger spaces above the bulkhead deck are to be provided; and at least one for each galley and for store room is to be provided.
3.4.16.2 In cargo ships and tankers, at least two portable fire extinguishers for each deck and at least one for each galley are to be provided.

3.4.17 Fire-extinguishing arrangements for paint lockers and flammable liquid lockers

3.4.17.1 Paint lockers and flammable liquid lockers are to be provided with a fire-extinguishing arrangement enabling the crew to extinguish a fire without entering the space.
3.4.17.2 For paint lockers and flammable liquid lockers of a deck area of 4 m^2 and more, one of the fixed arrangements as specified below are to be provided:
(1) a CO_2 system, designed for 40% of the gross volume of the space;
(2) a dry powder system, designed for at least 0.5 kg powder/m^3;
(3) a pressure water-spraying or an automatic sprinkler system, designed for 5 $l/m^2 \cdot min$.
3.4.17.3 The pressure water-spraying system may be connected to the ship's fire main.
3.4.17.4 Systems or arrangements other than those mentioned in 3.4.17.2(1), (2), (3) may be accepted by ISC provided that relevant technical and test data are provided.
3.4.17.5 For paint lockers and flammable liquid lockers of a deck area of less than 4 m^2, which do not give access to accommodation spaces, a CO_2 portable fire extinguisher sized to provide a minimum volume of free gas equal to 40% of the gross volume of the space may be accepted in lieu of a fixed system as specified in 3.4.17.2. The extinguisher may be discharged through a port on the wall of the locker. The required portable fire extinguisher is to be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water.

CHAPTER 4 INERT GAS SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This Chapter applies to ships fitted with the inert gas systems and nitrogen generator systems.

4.1.1.2 All types of inert gas systems are to comply with the following:

(1) An automatic control capable of producing suitable inert gas under all service conditions is to be fitted.

(2) Surveys are to be carried out at the intervals as required by PART ONE of the Rules.

4.1.2 Class notation

4.1.2.1 Inert gas systems complying with the requirements of this Chapter may be assigned the following class notation:

IGS

4.1.3 Plans and documents

4.1.3.1 In addition to the plans and documents required by relevant PARTs of the Rules, the following ones are to be submitted for approval:

(1) Details and arrangement of the inert gas generating plant including all control and monitoring devices;

(2) Arrangement of the piping system for distribution of the inert gas.

Section 2 INERT GAS SYSTEMS AND NITROGEN GENERATOR SYSTEMS OF DIFFERENT TYPES

4.2.1 Requirements for all inert gas systems on tankers, including chemical tankers, to which SOLAS regulation II-2/4.5.5.1 applies

4.2.1.1 An inert gas system complying with the applicable requirements of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), is to be fitted on tankers to which SOLAS regulation II-2/4.5.5.1 applies. In applying the applicable requirements of Chapter 15 of the FSS Code, any use of the word "Administration" therein is to be considered as meaning ISC. The inert gas system is to be operated in accordance with SOLAS regulation II-2/16.3.3, as amended by resolution MSC.365(93). In applying SOLAS regulation II-2/16.3.3.2, paragraph 2.2.1.2.4 of Chapter 15 of the FSS Code is to be complied with.

4.2.2 Additional requirements for nitrogen generator systems on tankers, including chemical tankers, to which SOLAS regulation II-2/4.5.5.1 applies

4.2.2.1 Where a nitrogen generator system is fitted on board as required by SOLAS regulation II-2/4.5.5.1, the inert gas is to be produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials. The following requirements are to be complied with.

4.2.2.2 In addition to the applicable requirements of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), the nitrogen generator system is to comply with SOLAS regulations II-2/4.5.3.4.2, 4.5.6.3 and 11.6.3.4.

4.2.2.3 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet paragraph 2.2.1.2.4 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93).

4.2.2.4 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with paragraph 2.2.1.2.5 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93). In addition to paragraph 2.2.2.4 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

4.2.2.5 The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas as required by 2.2.1.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93). Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

4.2.2.6 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by 2.4.1.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), is also to preserve the specification temperature.
4.2.2.7 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck. “Safe location” needs to address the two types of discharges separately:
(1) Oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
① outside of hazardous area;
② not within 3 m of areas traversed by personnel;
③ not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.
(2) Nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
① not within 3 m of areas traversed by personnel;
② not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.
4.2.2.8 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

4.2.3 Nitrogen / inert gas systems fitted for purposes other than inerting required by SOLAS regulations II-2/4.5.5.1 and 4.5.5.2
4.2.3.1 This paragraph applies to systems fitted on oil tankers, gas tankers or chemical tankers to which SOLAS regulations II-2/4.5.5.1 and 4.5.5.2 do not apply.
4.2.3.2 The systems are to comply with the requirements of 2.2.2.2, 2.2.2.4, 2.2.4.2, 2.2.4.3, 2.2.4.5.1.1, 2.2.4.5.1.2, 2.2.4.5.4, 2.4.1.1, 2.4.1.2, 2.4.1.3, 2.4.1.4, 2.4.2.1 and 2.4.2.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93).
4.2.3.3 The requirements of 4.2.2 of this Chapter apply to the systems except 4.2.2.1, 4.2.2.2, 4.2.2.3 and 4.2.2.5.
4.2.3.4 Materials used in inert gas systems are to be suitable for their intended purpose in accordance with the relevant requirements of ISC Rules for Materials and Welding.
4.2.3.5 All the equipment is to be installed on board and then tested under working conditions to meet the functional requirements and to be satisfactorily inspected by the Surveyor.
4.2.3.6 Two non-return devices as required by paragraph 2.2.3.1.1 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93) are to be fitted in the inert gas main. The non-return devices are to comply with the requirements of 2.2.3.1.2 and 2.2.3.1.3 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by paragraph 2.2.3.1.1 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), may be substituted by two non-return valves.

Section 3 EXAMINATION AND TESTING

4.3.1 General requirements
4.3.1.1 The devices and equipment required by this Chapter are, after having been installed on board, to be tested under working conditions to confirm their performance.

CHAPTER 5 HELICOPTER FACILITIES

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to all ships requesting the class notation specified in 5.1.2 below and fitted with areas and facilities for normal takeoff and landing of helicopters.

5.1.1.2 Helicopter deck facilities covered by this Chapter mean all deck structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters as well as any refueling and hangar facilities.

5.1.1.3 Helicopter deck structure, strength and arrangement, and related plans and documents to be submitted for approval are to comply with the requirements of Section 18, Chapter 2, PART TWO of the Rules.

5.1.2 Class notation

5.1.2.1 Ships complying with the requirements of this Chapter may be assigned the following class notation:

Helicopter Facilities

5.1.3 Plans and documents

5.1.3.1 The following plans and documents are to be submitted for approval:

(1) Arrangement of structural fire protection of helicopter deck, including fire division, means of escape, openings, drainage facilities;

(2) Arrangement of fire-fighting appliances provided for helicopter deck, including calculations of quantity of extinguishing agents to be used;

(3) Arrangement of helicopter refueling facilities and systems, where fitted.

5.1.4 Fire safety of helicopter deck

5.1.4.1 The fire prevention and fire extinction of helicopter deck is to comply with the requirements of SOLAS regulation II-2/18, other than those for personnel qualification, management, operation and maintenance.

5.1.4.2 Where the helicopter deck forms a part of the strength deck or a hatch cover, aluminum or other low melting point metal construction is not to be used.

5.1.4.3 The means of escape required for the helicopter deck may be used as working access for crew, provided the access is maintained clear.

5.1.4.4 Where the helicopter deck is of aluminum alloy that is made equivalent to steel, the drainage facilities thereof may also be made of aluminum alloy.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF **SEA-GOING STEEL SHIPS**

2024

PART SEVEN AUTOMATION SYSTEMS

Table of Contents

CHAPTER 1 GENERAL 1
Section 1 GENERAL PROVISIONS 1
CHAPTER 2 BASIC REQUIREMENTS 3
Section 1 GENERAL PROVISIONS 3
Section 2 CONTROL SYSTEMS 4
Section 3 SAFETY SYSTEMS 5
Section 4 ALARM SYSTEMS (INCLUDING DISPLAYS) 5
Section 5 CONTROL STATIONS (ROOMS) 6
Section 6 COMPUTER BASED SYSTEMS 7
Section 7 SENSORS 16
Section 8 MAIN PROPULSION MACHINERY REMOTELY CONTROLLED FROM NAVIGATION BRIDGE 16
CHAPTER 3 REQUIREMENTS FOR CLASS NOTATION AUT-0 OF PERIODICALLY UNATTENDED MACHINERY SPACES 18
Section 1 GENERAL PROVISIONS 18
Section 2 MAIN PROPULSION MACHINERY 18
Section 3 BOILERS 20
Section 4 ELECTRIC GENERATING PLANT 22
Section 5 AUXILIARY MACHINERY 23
Section 6 OTHER EQUIPMENT 23
Section 7 ADDITIONAL REQUIREMENTS FOR CONTROL STATIONS (ROOMS) 24
Section 8 ADDITIONAL REQUIREMENTS FOR CONTROL AND MONITORING SYSTEMS 25
Section 9 FIRE PRECAUTIONS AND PROTECTION AGAINST FLOODING 25
Section 10 AUTOMATIC CONTROL AND MONITORING ITEMS 27
CHAPTER 4 REQUIREMENTS FOR MACHINERY NOTATIONS OF CONSTANTLY ATTENDED MACHINERY SPACES 38
Section 1 GENERAL PROVISIONS 38
Section 2 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION MCC 38
Section 3 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION BRC 48

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 This PART applies to automated systems for machinery and electrical installations installed on sea-going ships.

1.1.1.2 The automated system in this PART covers control, safety and alarm systems (including displays).

1.1.1.3 Ships with different levels of automation complying with the requirements of this PART may be assigned the following class notations:

(1) AUT−0 — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the machinery spaces (including engine room centralized control station or room) periodically unattended;

(2) MCC — indicating that the machinery and electrical installations are capable of being operated with continuous supervision by watch-keepers from a centralized control station or room in the engine room;

(3) BRC — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the engine room attended by watch-keepers.

1.1.1.4 Ships with automated systems complying with the requirements of this PART are to be adaptable to all sailing conditions, including maneuvering.

1.1.1.5 The safety of the ships with automated systems complying with the requirements of this PART is to be same as that of the ships with machinery spaces being attended. Means are to be provided to ensure that the machinery and electrical equipment can be manually and effectively operated from a local position in case of failure of the automated systems.

1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) *Automatic control* means self-regulating control carrying out predetermined orders to operate the machinery without action by an operator.

(2) *Remote control* means control of a device by an operator from a distance through mechanical, electrical, electronic, pneumatic, hydraulic, electromagnetic (radio) or optical means or combination thereof.

(3) *Local control* means direct manual control by an operator of machinery through a device located on or adjacent to the controlled machinery.

(4) *Control stations* (*rooms*) means spaces fitted with monitoring means capable of controlling the machinery and electrical installations. They are mainly divided into four categories as follows in this PART:

① *centralized control station* (*room*) *of engine room* (abbreviated to ISC) means a control station (room) in which all monitoring means for automated equipment in engine room are concentrated;

② *bridge control station* (abbreviated to BCS) means a control station monitoring the propelling plant and other equipment in bridge;

③ *local control station* (abbreviated to LCS) means a control station where machinery and electrical installations are locally controlled;

④ *other control stations* mean control stations except the above-mentioned three ones.

(5) *Safety systems* mean systems which will operate automatically for safeguarding the machinery or electrical equipment in question in the following three modes of operation in case of serious faults endangering the main propulsion machinery, boilers, electric generating plants and other essential machinery or electrical equipment:

Mode a: immediate shutdown, e.g. emergency stop of main engines, emergency cutoff of boiler fuel oil supply and emergency cutoff of electric power supply to consumers. And such machinery or equipment is not to be put into operation again if without the manual resetting;

Mode b: the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g., by reducing the output or rotation speed of the machinery;

Mode c: the normal operating conditions are restored by starting of standby machinery.

(6) *Alarm* means a visual and audible signal of a predetermined out-of-limits parameter for the monitored machinery or system, which can identify the particular fault condition and its location within the machinery spaces, which can identify the particular fault condition and its location within the machinery spaces.

(7) *Group alarm* means a common alarm activated by any abnormal conditions of the monitored machinery or system.

(8) *Fail-safe principle* means that upon failure or malfunction of a component or system, the output automatically reverts to a predetermined design state of least critical consequence.
(9) *Override* means the special control measures for the skipping of a certain procedure or a certain safeguard action so as to effect compulsory operation to the machinery or electrical equipment for a short period to ensure the safety of the ship.
(10) *Emergency shutdown device* means a device independent of any control system and intended for manual activation in an emergency to stop the operation of machinery and electrical installations, e.g. emergency stop button of main engines, emergency cutoff button of boiler fuel oil supply and emergency cutoff button of electric power supply to consumers.
(11) *Redundancy design* means standby technical means to be used in case of system or equipment fault, by which a corresponding function can be taken over to continue an action or an original function is restored to continue the operation condition.
(12) *Node* means a point of interconnection to a data communication link.
(13) *Network* means a communication net for data transfer and exchange between computers.
(14) *Major modification* means one of the following cases or a combination thereof which will cause a substantial change to functions or safety features of an onboard computer system (excluding peripherals):

① change of hardware configuration;

② update of software;

③ alteration of network (including topology structure).

1.1.3 Plans and documents

1.1.3.1 Where a ship is intended to be assigned a machinery notation, the following plans and documents associated with control, alarm (display) and safety systems covered by this PART are to be submitted for approval:
(1) List of monitored and display points;
(2) List of alarm points (including display position and mode of alarms in the control station/room);
(3) Items of safety systems;
(4) Schematic diagrams of (electric, pneumatic, hydraulic) power supply to automated systems.
1.1.3.2 Additional plans and documents are to be submitted for approval as deemed necessary by ISC.

1.1.4 Certification of products

1.1.4.1 For certification requirements for the equipment and installations used in automated systems of a ship, see for details in Appendix 1A — List of Certification Requirements for Classed Marine Products of Chapter 3, PART ONE of the Rules.

1.1.5 Trials

1.1.5.1 The automated systems together with the associated machinery and electrical equipment are to be subject to mooring and sea trails in accordance with a test program approved by ISC for ascertaining the normal working of the whole system.
1.1.5.2 The setting of alarm points of automated systems and the preset parameters of safety systems which are determined in compliance with the requirements of the Rules as shown by the trials are to be recorded and maintained onboard for information.

CHAPTER 2 BASIC REQUIREMENTS

Section 1 GENERAL PROVISIONS

2.1.1 Environmental conditions

2.1.1.1 The automated systems are to operate satisfactorily within the ambient air temperatures as specified in 1.2.1.1(1) of Chapter 1, PART FOUR of the Rules.

2.1.1.2 The automated systems are to operate satisfactorily under the following conditions of relative humidity:

95% ± 3% at temperatures up to +45°C;

70% ± 3% at temperatures higher than +45°C.

2.1.1.3 The automated systems are to operate satisfactorily under the vibration conditions listed in Table 2.1.1.3. Where resonance occurs in the following frequency ranges and exceeds the required values, suitable means are to be provided for vibration damping.

Vibration **Table 2.1.1.3**

Location of installation	Parameters of vibration	
General space	2.0 ~ 13.2 Hz Amplitude ±1 mm	13.2 ~ 100 Hz Acceleration ±0.7 g
On reciprocating engines (e.g. diesel engines, air compressors) and other similar spaces	2.0 ~ 25 Hz Amplitude ±1.6 mm	25 ~ 100 Hz Acceleration ±4.0 g
Other special locations, e.g. exhaust pipes for (particularly medium or high speed) diesel engines	40 ~ 2,000 Hz Acceleration ±10.0 g (temperature 600°C)	

2.1.1.4 The automated systems are to operate satisfactorily under inclination and rolling conditions in all directions from the mounting position up to 22.5° (period 10 s) and under linear vertical acceleration of ±9.8 m/s^2.

2.1.1.5 The automated systems are to be suitable for the normal conditions encountered on board ships, e.g. salt air, oil-laden atmosphere, mould and dust.

2.1.2 Other working conditions

2.1.2.1 The automated system is to comply with the requirements of paragraphs 1.2.2 and 1.2.3 of Section 2, Chapter 1, PART FOUR of the Rules.

2.1.2.2 The automated system is to have necessary electromagnetic compatibility.

2.1.2.3 The hydraulic and pneumatic equipment of automated systems is to operate satisfactorily under pressure variations in the system by ±20% of the rated values and is not to be damaged by transient pressure rise up to 1.5 times the rated pressure.

2.1.3 Fail-safe

2.1.3.1 Control systems, alarm systems and safety systems are to be designed on the fail-safe principle. The fail-safe principle is to be applied on the basis not only of the automated system itself and its associated machinery, but also of the whole machinery installation and the safety of the ship and personnel.

2.1.3.2 The design of the control system, alarm system and safety system is to be such that a failure in the operation will not cause other failures and will, so far as possible, lead to the least dangerous condition of the controlled process.

2.1.3.3 The automatic control and remote control systems are to ensure continuous, effective and reliable operation.

2.1.4 Independence

2.1.4.1 Control, safety and alarm systems are to be designed or rendered to function independently of each other so that a failure or malfunction in one or two of these systems will not prevent the other system(s) from operating.

2.1.4.2 In any case, a safety system of mode a is to function independently of control and alarm systems so that a failure or malfunction in these systems will not prevent the safety system from operating. For the safety systems of modes b and c, complete independence of other control and alarm systems is not required.

2.1.4.3 Safety systems of different units of the machinery plant are to be independent. Failure in the safety system of one part of the plant is not to interfere with the operation of the safety system in another part of the plant.

2.1.5 Examination and lock-in

2.1.5.1 The functions of control, safety and alarm systems are to be capable of being examined. Where the settings, e.g. sensitivity and limiting values of the control, safety and alarm equipment may be regulated, these regulated values are to be such that they may be easily examined, identified and locked-in.

2.1.6 Power supply

2.1.6.1 The safety and alarm systems and control systems (e.g. automated systems of an electric generating plant) requiring continuous use in the event of a failure of normal power supply are to be capable of being automatically changed over to an independent standby power supply. The standby power supply may be an accumulator battery, with a capacity at least sufficient for a period of supply of 30 min. Where such systems could be adversely affected by an interruption in power supply, change-over to the standby power supply is to be achieved without a break.

2.1.6.2 A visual and audible alarm is to be given in the event of a failure of power supply① for safety system, alarm system and control system.

2.1.6.3 Control system, safety system and alarm system are to be supplied by independent final sub circuit and protected against short circuit and overload.

Section 2 CONTROL SYSTEMS

2.2.1 General requirements

2.2.1.1 Control systems include automatic and remote control systems.

2.2.1.2 Control systems are to have good control properties. Control systems for the operation of machinery and electrical equipment are to have satisfactory characteristics, i.e., to be stable throughout their operating range so that the operation of the controls will not induce detrimental mechanical or thermal loads. Control systems are also to have necessary accuracy of control.

2.2.1.3 The design of the control system is to be such that a failure in the control system will lead to the least dangerous condition of the controlled process and furthermore, such failure is not to render any reserved automatic or manual control, or both, inoperative.

2.2.1.4 All machinery and electrical installations essential for the safe operation of the ship are, in the case of failure in or out-of-action of any part of automatic or remote control system including failure of power supply, to be capable of:

(1) sending out alarm signals;

(2) replacing immediately faulty component(s) or putting the back-up arrangements into service in time for recovering normal operation (if applicable);

(3) transferring to local manual control, and the transfer of control is not to seriously affect the operating conditions of the machinery and electrical equipment.

2.2.1.5 Control systems for the main propulsion machinery (including main engine and controllable pitch propeller), boilers and electric generating plant are to be independent of each other unless necessary for operation. The control system for each independent propulsion engine is to be provided separately.

2.2.1.6 Where necessary measures are taken to ensure effective monitoring of the partly common equipment in the systems mentioned in 2.1.4.1 above and an alarm is given in case of any failure in such equipment, a partly common use of the equipment may be permitted (see also 2.7.1.4 of this Chapter).

2.2.2 Hydraulic and pneumatic power sources

2.2.2.1 The hydraulic power source and piping of control systems are to comply with the relevant requirements of Chapter 2 and Section 7 of Chapter 4, PART THREE of the Rules, and the following requirements:

(1) The standby hydraulic pump is to start and operate automatically when the discharge pressure from the working pumps falls below a predetermined value and an alarm is to be given.

(2) Where the hydraulic pressure is lower than the required normal working pressure, an alarm is to be given.

2.2.2.2 The pneumatic power source and piping of control systems are to comply with the relevant requirements of Chapter 2, PART THREE of the Rules and the following requirements:

---

① A visual and audible alarm is to be given in the event of a failure of power supply for engine room centralized monitoring and alarm system. For alarms of safety system, alarm system and control system of other equipment in the event of a failure of power supply, refer to Table 3.10.1.1 of Chapter 3 of this PART.

(1) Air vessels for pneumatic controls may be supplied from the main engine starting air vessels or from exclusive air compressors.
(2) Where air vessels are supplied from the exclusive air compressors, at least two compressors are to be provided, one of which is standby, or from one exclusive air compressor and the main air vessel. The air compressors are to start and operate automatically when the air pressure falls below a predetermined value.
(3) Relief valves are to be fitted in the pneumatic control piping, which are to be set to open at a pressure not greater than 1.1 times the normal working pressure.
(4) Reducing valves, filters, oil separators and driers are to be provided in the pneumatic control piping so as to ensure dry, clean and oil-free air to the pneumatic controls. The reducing valves, filters and driers are to be, in general, fitted each in duplicate and in parallel. The provision of a single filter and a single drier may be permitted, provided that means are provided to ensure quick maintenance and renewal of the above-mentioned devices without interrupting the normal operation of the pneumatic control system.

Section 3 SAFETY SYSTEMS

2.3.1 General requirements

2.3.1.1 In case of serious faults endangering the main propulsion engines, boilers, electric generating plants and other essential machinery and electrical equipment, the safety systems are to operate automatically for safeguarding the machinery or electrical equipment in question in the three modes of operation required in 1.1.2.1(5) of this PART and alarms are to be given.
2.3.1.2 When the system has stopped a unit, the unit is not to be restarted automatically before a manual reset has been made.
2.3.1.3 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of alarm system by:
(1) starting of standby units;
(2) load reduction or shutdown, such that the least drastic action is taken first.
2.3.1.4 When the system has been activated, audible and visual alarms are to be given in control station to trace the cause of the safety action.

2.3.2 Means of overriding

2.3.2.1 For the purpose of ensuring the safety of ships, main propulsion machinery systems, such as main diesel engines, steam turbines, gas turbines and electric propulsion systems, are in general to be provided with arrangements for overriding.
2.3.2.2 An indication is to be given and a suitable alarm is to be activated when an overriding action is operated.
2.3.2.3 Means are to be provided to preclude inadvertent operation of the overriding function.

2.3.3 Pneumatic power source and piping

2.3.3.1 The pneumatic power source and piping of safety systems are to be in compliance with the requirements of 2.2.2 of this Chapter, and the pneumatic pipelines are to be as far as practicable separated from the control systems.

Section 4 ALARM SYSTEMS (INCLUDING DISPLAYS)

2.4.1 General requirements

2.4.1.1 All faults of the controlled and monitored machinery or electrical equipment and their control and monitoring systems are to be indicated with alarm signals at the relevant control stations (rooms) so that the engineering personnel on duty are made aware that a machinery fault has occurred.
2.4.1.2 All alarms are to be both audible and visual. According to the nature of faults, the colors used for visual signals are to be, in general, red for vital faults and yellow for general ones. Audible signal is to be of an adequate sound level and to be clearly distinguishable from the fire alarms, telephones and other sound signals (e.g. CO_2 flooding).
2.4.1.3 The alarm system is to be capable of indicating all faults occurred at the same time, and the operation and/or acknowledgement of any alarm is not to inhibit the operation and/or acknowledgement of other alarms occurred at the same time.

2.4.1.4 Arrangements may be fitted to extinguish (silence) audible alarm signals. When alarms are acknowledged and the silencing button is pressed, visual alarm signals are not to be extinguished, but may be altered, for example, from flashing to a steady light, and remain clearly visible. The local silencing of bridge or accommodation alarms is not to stop the audible machinery space alarm. The silencing button for the audible alarms in machinery spaces is permitted to be arranged only in the machinery space or at the engine room centralized control station and the visual alarm signals are to be retained until the fault has been rectified. When the fault has been rectified, the alarm system is to be automatically reset to its normal operating condition.
2.4.1.5 Where a single alarm has been shown in the local control station of engine room, the alarm signal is also to be shown in other relevant remote control stations and may be displayed by means of group alarm.

2.4.2 Inspection and self-monitoring of alarm systems
2.4.2.1 The alarm system is to be designed with self-monitoring properties, i.e., any fault in the alarm system should cause it to detect itself automatically and fall into the alarm (or indication) condition. The extent and depth of self-monitoring is to be determined in connection with the measures taken for maintenance and renewal.
2.4.2.2 The alarm system is to be capable of blockading meaningless signals during certain processes. Manual blockading is to be indicated.

2.4.3 Displays
2.4.3.1 Parameters may be clearly displayed by instrumentation or display units. Parameter displays may be performed separately or selectively, and may be alphanumeric or in the form of graphics or diagrams. But all displays or indications are to be clearly distinguishable. The color of indicating lamps is normally to be green or white. For display units incorporating with computers and the specific requirements for display, IEC 60092-504 Electrical installations in ships - Part 504: Automation, control and instrumentation is to be complied.

Section 5 CONTROL STATIONS (ROOMS)

2.5.1 Arrangement of control stations (rooms)
2.5.1.1 The engine room centralized control station (room) (abbreviated to ISC) is generally to be located within the machinery spaces.
2.5.1.2 The ISC is to be located as far as possible in a position of least vibrations and of low noise level while the ship operates at sea.
2.5.1.3 The ISC within the machinery spaces is to be of the sound-proof construction, with the window glass of the shatter-resistant type. The ISC is to have two means of access located as far remote from each other as practicable, and one of which is to be as far as possible situated near the escape trunk of the machinery spaces or the special purpose escape trunk.
2.5.1.4 The control and monitoring equipment, signal displays, control levers, switches and push buttons within the control stations (rooms) are to be arranged with due attention to thorough ergonomics for the convenience of operation, surveillance, maintenance and the safety of the operators.
2.5.1.5 The local control stations are to comply with the relevant requirements of 1.1.1.5 and 2.5.2 of this PART. It is to be possible for the propulsion machinery to be controlled from a local position even in the case of failure or malfunction in any part of the automatic or remote control systems of any other control station or the propulsion machinery.

2.5.2 Transfer of control
2.5.2.1 Transfer of control between control stations is to be possible to the machinery and electrical equipment under common control from such stations, either when these machinery and electrical equipment are in normal operation or in case of their failures. Such changeover is not to seriously affect the operating conditions of the machinery and electrical equipment.
2.5.2.2 The transfer of control between the ISC and BCS is to be possible only at the ISC, and the transfer of control between the LCS and ISC or BCS is to be possible only at the LCS.
2.5.2.3 Changeover between control stations is to be so arranged that it may be effected only with the acceptance of the station taking control.
2.5.2.4 Provision is to be made at all control stations (rooms) to indicate which station is in control.

2.5.2.5 Where machinery and electrical equipment may be controlled from two or more control stations (rooms), control is to be possible only from one control station at one time. At all control stations, interconnected control positions for the controllers for main propulsion machinery are permitted.
2.5.2.6 Propulsion machinery orders from the navigating bridge are to be indicated at all control positions for the machinery.
2.5.2.7 Where the manual control gear of the main engine or other machinery and electrical equipment is extended directly to the ISC by means of mechanical linkage, the provision of corresponding LCS may be exempted.

2.5.3 Other control stations

2.5.3.1 For the arrangement of other control stations which are in close relation to the safety of machinery and electrical equipment or the safety of the ship, relevant technical information (e.g. arrangement plan, specification of monitoring properties) are to be provided and the relevant requirements of this PART are to be complied with.

Section 6 COMPUTER BASED SYSTEMS

2.6.1 General requirements

2.6.1.1 This Section applies to design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions. This Section applies to systems which provide control, alarm, monitoring, safety, or internal vessel communication functions that are subject to classification requirements. This Section does not apply to computer-based systems that are covered by statutory regulations, e.g. loading instruments/ stability computer① and radio communication and navigation equipment covered by SOLAS chapters IV and V.
2.6.1.2 Computer based systems are, in addition to satisfying the requirements of this Section, to satisfy relevant requirements in the Guidelines for Type Approval Test of Electric and Electronic Products and the class notation Cyber Security (P) in the Guidelines for Ship Cyber Security.
2.6.1.3 The following standards may be used for the development of hardware/software of computer based systems:
(1) IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems;
(2) ISO/IEC/IEEE 12207 Systems and software engineering – Software life cycle processes;
(3) ISO 9001 Quality Management Systems – Requirements;
(4) ISO/IEC/IEEE 90003 Software engineering - Guidelines for the application of ISO 9001:2015 to computer software;
(5) IEC 60092-504 Electrical installations in ships - Part 504: Special features - Control and instrumentation;
(6) ISO/IEC 25000 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE;
(7) ISO/IEC 25041 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators;
(8) IEC 61511 Functional safety - Safety instrumented systems for the process industry sector;
(9) ISO/IEC/IEEE 15288 Systems and software engineering - System life cycle process;
(10) ISO 10007 Quality management – Guidelines for configuration management;
(11) ISO 24060 Ships and marine technology - Ship software logging system for operational technology.
Other standards accepted by ISC may also be considered.

2.6.2 Definitions

2.6.2.1 For the purpose of this Section:
(1) Black-box description: A description of a system's functionality and behaviour and performance as observed from outside the system in question.
(2) Black-box test methods: Verification of the functionality, performance, and robustness of a system, sub-system or component by only manipulating the inputs and observing the outputs. This does not require any knowledge of the system's inner workings and focuses only on the observable behaviour of the system/component under test in order to achieve the desired level of verification.
(3) Computer-based system(CBS): A programmable electronic device, or interoperable set of

① Refer to the requirements of Appendix 1 and Appendix 2 of Chapter 2, PART TWO of the Rules.

programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBSs onboard include IT and OT systems. A CBS may be a combination of subsystems connected via network. Onboard CBSs may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels' CBSs and/or other facilities.

(4) Failure mode description: A document describing the effects due to failures in the system, not failures in the equipment supported by the system. The following aspects shall be covered:

① list of failures which are subject to assessment, with

② description of the system response to each of the above failures

③ comments to the consequence of each of these failures.

(5) Parameterization: To configure and tune system and software functionality by changing parameters. It does not usually require-computer programming and is normally done by the system supplier or a service provider, not the operator or end-user.

(6) Programmable device: Physical component where software is installed.

(7) Robustness: The ability to respond to abnormal inputs and conditions.

(8) Simulation test: Monitoring, control, or safety system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

(9) Software component: A standalone piece of code that provides specific and closely coupled functionality.

(10) Software master files: The computer-files that constitutes the original source of the software. For custom made software this may be readable source- code files, and for COTS software it may be different forms of binary files.

(11) Software-structure: Overview of how the different software components interact and is commonly referred to as the Software Architecture, or Software Hierarchy.

(12) Sub-system: Identifiable part of a system, which may perform a specific function or set of functions.

(13) System: A combination of components, equipment and logic which has a defined purpose, functionality, and performance. In the context of this Section, a specific system is delivered by one system supplier.

(14) System of systems: A system which is made up of several systems In the context of this Section, the system of systems encompasses all monitoring, control and safety systems delivered from the Shipyard as a part of a vessel.

(15) Owner: The organization or person which orders the vessel in the construction phase or the organization which owns or manages the vessel in service. In the context of this Section this is a defined role with specific responsibilities.

(16) Supplier: A generic term used for any organisation or person that is a contracted or a subcontracted provider of services, system components, or software.

(17) Service supplier: A person or company, not employed by an IACS Member, who at the request of an equipment manufacturer, shipyard, vessel's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services.

(18) System supplier: An organisation or person that is contracted or a subcontracted provider of system components or software under the coordination of the Systems integrator. In the context of this Section this is a defined role with specific responsibilities.

(19) Systems integrator: Single organization or a person coordinating interaction between suppliers of systems and sub-systems on all stages of life cycle of computer-based systems in order to integrate them into a verified vessel-wide system of systems and to provide proper operation and maintenance of the computer based systems. In the context of this Section this is a defined role with specific responsibilities. During the design and delivery phase the Shipyard is the default Systems integrator, during operations phase the Owner is the default.

(20) Vessel: Ship or offshore unit where the computer-based system is to be installed.

2.6.3 Approval of system and components

2.6.3.1 Computer-based systems that are necessary to accomplish vessel-functions of category II or category III shall be delivered with a vessel-specific Society certificate. The objective of the vessel-specific system certification is to confirm that design and manufacturing of the system has been completed and that the system complies with applicable rules of the classification Society. Vessel-specific system certification consist of two main verification activities:

(1) Assessment of vessel-specific documentation (see documents listed in Table 2.6.4.1(1));
(2) Survey and testing of the system to be delivered to the vessel.
ISC may accept Alternative Certification Scheme (ACS) provided that the requirements are met, and that the system is provided with a vessel-specific certificate.

2.6.3.2 Computer-based systems that are routinely manufactured and include standardized software functions may be type approved in accordance with specified rules of ISC. The type approval consist of two main verification activities:
(1) Assessment of type-specific documentation, including documents listed in Table 2.6.4.1(1) and other documents required to apply for ISC type approval;
(2) Survey and testing of the standardized functions.
Type approval will normally not yield exemption from vessel-specific system certification since vessel-specific functions, parameter configurations and installation elements demand vessel specific verification.

2.6.4 Plans and documents

2.6.4.1 Plans and documents are to be submitted to ISC in accordance with the requirements of Tables 2.6.4.1(1) and 2.6.4.1(2) for computer based systems. Items in Table 2.6.4.1(3) are to be witnessed and surveyed by ISC surveyors.

Plans and documents to be submitted by system supplier **Table 2.6.4.1(1)**

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	Ⓘ	Ⓘ
2	System description	Ⓘ(if necessary)	Ⓐ	Ⓐ
3	Environmental compliance testing report	Ⓘ(if necessary)	Ⓘ	Ⓘ
4	Software testing report	—	Ⓘ(if necessary)	Ⓘ(if necessary)
5	System testing report	—	Ⓘ(if necessary)	Ⓘ(if necessary)
6	FAT program	—	Ⓐ	Ⓐ
7	FAT report	—	Ⓘ	Ⓘ
8	Additional FAT documents (e.g. user manuals)	—	Ⓘ(if necessary)	Ⓘ(if necessary)
9	Change management procedure	—	Ⓘ	Ⓘ

Plans and documents to be submitted by system integrator **Table 2.6.4.1(2)**

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	Ⓘ	Ⓘ
2	List of system category	Ⓐ	Ⓐ	Ⓐ
3	Risk assessment report	Ⓐ(if necessary)	Ⓐ(if necessary)	Ⓐ(if necessary)
4	Vessel's system-architecture description	Ⓘ	Ⓘ	Ⓘ
5	SAT program	—	Ⓐ	Ⓐ
6	SAT report	—	Ⓘ	Ⓘ
7	SOST program	—	Ⓐ	Ⓐ
8	SOST report	—	Ⓘ	Ⓘ
9	Software change management procedure	—	Ⓘ	Ⓘ

Items to be witnessed or surveyed by surveyors **Table 2.6.4.1(3)**

No.	Item	Responsible	System category		
			Category I	Category II	Category III

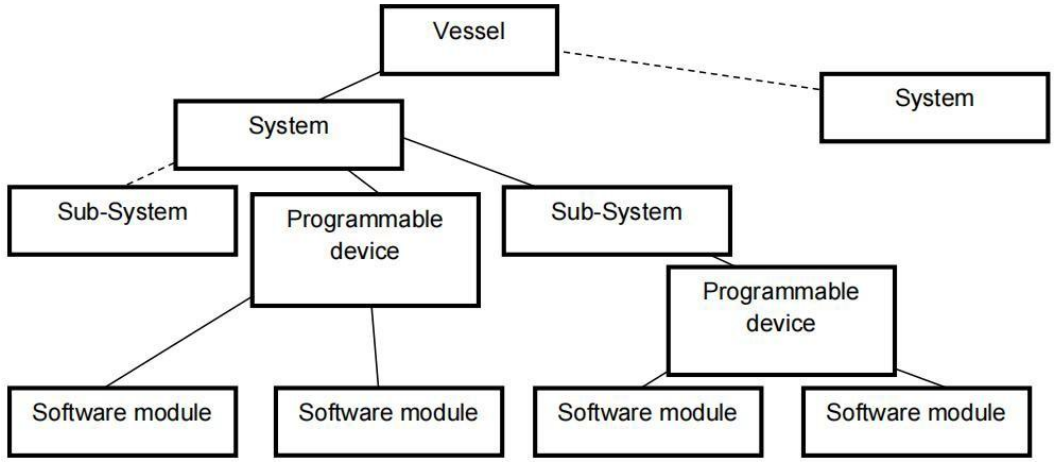
1	FAT	System supplier	—	Ⓦ	Ⓦ
2	SAT	System integrator	—	Ⓦ	Ⓦ
3	SOST	System integrator	—	Ⓦ	Ⓦ
4	Verification of Changes	System integrator	—	Ⓦ	Ⓦ

Note: The meanings of symbols used in the Table are as follows:

Ⓐ Submitted to ISC for approval; ① Provided to ISC for information; Ⓦ To be witnessed or surveyed by ISC surveyors.

2.6.5 Structure and category of computer based system

2.6.5.1 The hierarchy and relationships of a typical computer based system are as shown in Figure 2.6.5.1.



Note: Dashed lines show non-developed branches of diagram

Figure 2.6.5.1 Illustrative System Hierarchy

2.6.5.2 The categorization of a system is based on the potential severity of the consequences if the system serving the function fails. Table 2.6.5.2 provides the definitions of the categories.

System categories **Table 2.6.5.2**

Category	Failure effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Monitoring, informational and administrative functions
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Vessel alarm, monitoring and control functions which are necessary to maintain the vessel in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous or catastrophic situations for human safety, safety of the vessel and/or threat to the environment.	- Control functions for maintaining the vessel's propulsion and steering - Vessel safety functions

2.6.5.3 Category I systems are normally not subject to verification by ISC, as failure of these systems shall not lead to dangerous situations. However, information pertinent to category I systems shall be required upon request to determine the correct category or ensure that they do not influence the operation of systems in category II and category III. The category of a system shall always be evaluated in the context of the specific vessel in question; thus, the categorization of a system may vary from one vessel to the next. This means that the examples of categories below are given as guidance only, the systems are not exhaustive.

(1) Category I systems:

① Fuel monitoring system;

② Maintenance support system;

③ Diagnostics and troubleshooting system;
④ Closed circuit television;
⑤ Cabin security, entertainment system;
⑥ Fish detection system.

(2) Category II systems:
① Fuel oil treatment system;
② Alarm monitoring and safety systems for propulsion and auxiliary machinery;
③ Inert gas system;
④ Control, monitoring and safety system for cargo containment system;
⑤ Monitoring and safety system.

(3) Category III systems:
① Propulsion control system;
② Steering gear control system;
③ Electric power system (including power management system);
④ Dynamic positioning system (DP 2 and DP 3).

2.6.6 Requirements on development and certification of computer-based system

2.6.6.1 A global top-down approach shall be undertaken in the design and development of both hardware and software and the integration in sub-systems, systems, and system of systems, spanning the complete system lifecycle. This approach shall be based on the standards as listed herein or other standards recognized by ISC.

2.6.6.2 Systems integrators and system suppliers shall, in the development of computer-based systems for category II and category III, comply to a recognised quality standard such as ISO 9001; also incorporating principles of IEC/ISO 90003. The quality system is certified as compliant to a recognized standard by an organisation with accreditation under a national accreditation scheme or ISC confirms compliance to a standard through a specific assessment of the quality system. The quality system shall as a minimum include the following topics in Table 2.6.6.2:

Quality system **Table 2.6.6.2**

Area		Role	
No.	Topic	System supplier	System integrator
1	Responsibilities and competency of the staff	x	x
2	The complete lifecycle of delivered software and of associated hardware	x	x
3	Specific procedure for unique identification of a computer-based system, its components and versions	x	
4	Creation and update of the vessel's system architecture		x
5	Organization set in place for acquisition of software and related hardware from suppliers	x	x
6	Organization set in place for software code writing and verification	x	
7	Organization set in place for system validation before integration in the vessel	x	
8	Specific procedure for conducting and approving of systems at FAT and SAT	x	x
9	Creation and update of system documentation	x	
10	Specific procedure for software modification and installation on board the vessel, including interactions with shipyard and owner	x	x
11	Specific procedures for verification of software code	x	
12	Procedures for integrating systems with other systems and testing of the system of systems for the vessel	x	x
13	Procedures for managing changes to software and configurations before FAT	x	
14	Procedures for managing and documenting changes to software and configurations after FAT	x	x
15	Checkpoints for the organization's own follow-up of adherence to the quality system	x	x

2.6.7 Requirements on the system supplier

2.6.7.1 The system supplier shall define a quality plan (No.1 in Table 2.6.4.1(1)) and document that the quality management system is applied for the design, construction, delivery, and maintenance of the specific system to be delivered. All applicable items described in Table 2.6.6.2 (for the system supplier role) shall be demonstrated to exist and being followed, as relevant.

2.6.7.2 A method for unique identification of a system, its different software components and different revisions of the same software component shall be applied. The method shall be applied throughout the lifecycle of the system and the software. The documentation of the method is typically a part of the quality management system. Technical requirements for unique identification of systems and software are given in 2.6.11.1 of this Section.

2.6.7.3 The system's specification and design shall be determined and documented in a system description (No.2 in Table 2.6.4.1(1)). In addition to serve as a specification for the detailed design and implementation, the purpose of the system description is to document that the entire system-delivery is according to the specifications and in compliance with applicable rules and regulations. The system description shall contain information of the following:

(1) Purpose and main functions, including any safety aspects;
(2) System category as defined;
(3) Key performance characteristics;
(4) Compliance with the technical requirements and ISC rules;
(5) User interfaces/mimics;
(6) Communication and Interface aspects: Identification and description of interfaces to other vessel systems;
(7) Hardware-arrangement related aspects:

① Network-architecture/topology, including all network components like switches, routers, gateways, firewalls etc.;
② Internal structure with regards to all interfaces and hardware nodes in the system (e.g. operator stations, displays, computers, programmable devices, sensors, actuators, I/O modules etc.);
③ I/O allocation (mapping of field devices to channel, communication link, hardware unit, logic function);
④ Power supply arrangement;
⑤ Failure mode description.

2.6.7.4 Evidence of environmental type testing (No.3 in Table 2.6.4.1(1)) according to ISC Guidelines for Type Approval Test of Electric and Electronic Products regarding hardware elements included in the system and sub-systems shall be submitted to ISC.

2.6.7.5 The software created, changed, or configured for the delivery project shall be developed and have the quality assurance activities assessed according to the selected standard(s) as described in the quality plan. The quality assurance activities may be performed on several levels of the software -structure and shall include both custom-made software and configured components (e.g. software libraries) as appropriate. For components in systems of Category II and III, the scope, purpose, and results of all performed reviews, analyses, tests, and other verification activities shall be documented in test reports (No.4 in Table 2.6.4.1(1)). The verification of the software shall as a minimum verify the following aspects based on black-box methods[①]:

(1) Correctness, completeness and consistency of any parameterization and configuration of software components;
(2) Intended functionality;
(3) Intended robustness.

2.6.7.6 The system shall as far as practicable be tested before the FAT. The main purpose of the system test is for the system supplier to verify that the entire system delivery is according to the specifications, approved documentation and in compliance with applicable rules and regulations; and further, that the system is completed and ready for the FAT. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. Some of the testing may be performed by utilizing simulators and replica hardware. The test-environment shall be documented, including a description of any simulators, emulators, test-stubs, test-management tools, or other tools affecting the test environment and its limitations. Test cases and test results shall be documented in test programs and test reports (No.5 in Table 2.6.4.1(1)) respectively. The testing shall at least verify the following aspects of the

---

① Some of the methods utilized in this activity are sometimes referred to as "software unit test" or "developer test" and may also include verification methods like code-reviews and static- or dynamic code analysis.

system:
(1) Functionality;
(2) Effect of faults and failures (including diagnostic functions, detection, alerts response);
(3) Performance;
(4) Integration between software and hardware components;
(5) Human-machine interfaces;
(6) Interfaces to other systems.

2.6.7.7 A factory acceptance test (FAT) shall be arranged for the system in question. The main purpose of the FAT is to demonstrate to ISC that the system is completed and compliant with applicable classification rules, thus enabling issuance of a Society Certificate for the system. The FAT test program (No.6 in Table 2.6.4.1(1)) shall cover a representative selection of the test items from the internal system test (described in 2.6.7.6 of this Section), including normal system functionality and response to failures. For category II and III systems, network testing to verify the network resilience requirements in 2.6.11.2 of this Section shall be performed. If agreed by all parties, the network testing may be performed as a part of the system test onboard the vessel. The FAT shall as a rule be performed with the project specific software operating on the actual hardware components to be installed on board, with necessary means for simulation of functions and failure responses, however other solutions such as replica hardware or simulated hardware (emulators) may be agreed with ISC. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.7 in Table 2.6.4.1(1)). The test report shall also contain a list of the software (including software versions) that were installed in the system when the test was executed[①].

2.6.7.8 The initial installation and subsequent updates of the software components of the system shall be done according to a management of change procedure which has been agreed between the system supplier and the systems integrator. The management of change procedure shall comply with the requirements in 2.6.10 of this Section. Cyber security measures shall be observed as described in ISC Guidelines for Ship Cyber Security.

2.6.8 Requirements on the systems integrator

2.6.8.1 For the purposes of this Section, the Shipyard is considered as the systems integrator in the development and delivery phase unless another organization or person is explicitly appointed by the Shipyard.

2.6.8.2 The systems integrator shall define a quality plan (No.1 in Table 2.6.4.2(1)) and document that the quality management system is applied for the installation, integration, completion, and maintenance of the systems to be installed on board. All applicable items described in Table 2.6.6.2 (for the systems integrator role) shall be demonstrated to exist and being followed, as relevant.

2.6.8.3 For each system delivery to a particular vessel, it shall be decided which category the system falls under based on the failure effects of the system (as defined in 2.6.5.2 of this Section). The category for a specific system must be conveyed to the relevant system supplier. ISC may decide that a risk-assessment[②] (No.3 in Table 2.6.4.1(2)) is needed to verify the proper system category.

2.6.8.4 The system of systems (SoS) shall be specified and documented (No.4 in Table 2.6.4.1(2)). This architecture specification provides the basis for category determination and development of the different integrated systems by allocating functionality to individual systems and by identifying the main interfaces between the systems[③]. It shall also serve as a basis for the testing of the integrated systems on the vessel level (see 2.6.8.6 of this Section).

The vessel's system architecture shall at least contain description of:
(1)Overview of the total systems architecture (the system of systems);
(2)Each system's purpose and main functionality;
(3)Communication and interface aspects between different systems.

2.6.8.5 A system acceptance test shall be arranged onboard the vessel. The main purpose of the system acceptance test (SAT) is to verify the system functionality, after installation and integration with the applicable machinery/electrical/process systems on board including possible interfaces with other control and monitoring systems. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.6 in Table 2.6.4.1(2)). The test report shall also contain a list of the

---

① For complex systems there may be a large difference in scope between the "Internal system testing before FAT" activity and the FAT, while for some systems the scope may be identical.

② IEC/ISO31010 "Risk management - Risk assessment techniques" may be used as guidance in order to determine method of risk assessment.

③ See network topology in ISC Guidelines for Ship Cyber Security.

software (including software versions) that were installed in the system when the test was executed.

2.6.8.6 Integration tests shall be conducted after installation and integration of the different systems in its final environment on board[①]. The purpose of the tests is to verify the functionality of the complete installation (system of systems) including all interfaces and inter-dependencies in compliance with requirements and specifications. The testing shall at least verify the following aspects of the system of systems:

(1) The overall functionality of the interacting systems as a whole;
(2) Failure response between systems;
(3) Performance;
(4) Human-machine interfaces;
(5) Interfaces between the different systems.

2.6.8.7 The systems integrator shall follow procedures for management of change (No.9 in Table 2.6.4.1(2)) to the system as described in 2.6.10 of this Section.

2.6.9 Requirements on maintenance of computer-based systems

2.6.9.1 For the purposes of this Section, the vessel owner is considered to be the systems integrator in the operations phase unless another organization or person is explicitly appointed by the owner. Accordingly, ISC shall in a timely manner be informed by the owner about the appointed systems integrator which is responsible for implementing any changes to the systems in conjunction with system supplier(s).

2.6.9.2 The systems integrator shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure(s). For details about change management please see paragraph 2.6.10 of this Section.

2.6.9.3 Changes to computer-based systems in the operational phase shall be recorded. The records shall contain information about the relevant software versions and other relevant information as described in 2.6.10.9 of this Section.

2.6.9.4 The system supplier shall follow procedures for maintenance of the system including procedures for management of change as described in 2.6.10 of this Section.

2.6.9.5 The system supplier shall make sure that the planned changes to a system have passed relevant in-house tests before the change is made to systems on board.

2.6.10 Management of change

2.6.10.1 The management of change process shall be coordinated and agreed between the relevant stakeholders along the different stages of the lifecycle of the computer-based system[②]. If changes are required to a system after it has been approved by applicable stakeholders (typically the systems integrator and ISC at FAT) the modifications shall follow defined change management procedures.

2.6.10.2 The change management procedures cover both hardware and software. After FAT, the system supplier shall manage all changes to the system in accordance with the procedure. Examples could be qualification of new versions of acquired software, new hardware, modified control logic, changes to configurable parameters. The procedure(s) shall at least describe the activities listed in 2.6.10.3 to 2.6.10.10 of this Section.

2.6.10.3 The system supplier shall make sure that each system and software version is uniquely identifiable, see 2.6.7.2 of this Section.

2.6.10.4 There shall be defined mechanisms for handling of the files that constitutes the master-files for a software component. Personnel authorities shall be clearly defined along with the tools and mechanisms used to ensure the integrity of the master files.

2.6.10.5 It shall be clearly defined how to perform backup and restoration of the software components of a computer-based system onboard the vessel.

2.6.10.6 Before a change to the system is made, an impact analysis shall be performed in order to determine to what extent the change activities shall be performed. The analysis shall:

(1) Determine the criticality of the change.
(2) Determine the impact on existing documentation.

---

① For complex systems there may be a large difference in scope between the "System acceptance test (SAT) onboard the vessel" activity and the SOST, while for some systems the scope may be overlapping or identical. It is possible to combine the two activities into one when the test scope is similar.

② Typically, the management of change address at least three different stages: Development and internal verification before FAT, involving the system supplier and sub-suppliers; From FAT to handover of the vessel to the owner, involving the system supplier, the systems integrator, ISC, and the owner; In operation, involving the system supplier, service suppliers, the owner, and ISC.

(3) Determine the needed verification and test activities.
(4) Determine the need to inform other stakeholders about the change.
(5) Determine the need to obtain approval from other stakeholders (e.g. ISC and or Owner) before the change is made.
2.6.10.7 When maintenance includes installation of new versions of the software in the system, it shall be possible to perform a rollback of the software to the previous installed version with the purpose of returning the system to a known, stable state. Roll-backs shall be documented and analysed to find and eliminate the root cause.
2.6.10.8 To the largest degree practically possible, modifications shall be verified before being installed onboard. After installation, the modification(s) shall be verified onboard according to a documented verification program containing:
(1) Verification that the new functionalities and/or improvements have had the intended effect.
(2) Regression test to verify that the modification has not had any negative effects on functionality or capabilities that was not expected to be affected.
2.6.10.9 Changes to systems and software shall be documented in change records to allow for visibility and traceability of the changes. The change records shall contain at least the following items:
(1) The purpose for a change;
(2) A description of the changes and modifications;
(3) The main conclusions from the impact analysis (see 2.6.10.6 of this Section);
(4) The identity and version of any new system or software version(s) (see 2.6.10.3 of this Section);
(5) Test reports or tests summaries (see 2.6.10.8 of this Section).
2.6.10.10 Documentation of the changes to software may be recorded in the planned maintenance system (PMS), in a software registry or equivalent.
2.6.10.11 During in operation (vessel in service) phase, the verification by ISC regarding the management of change in operation is generally performed during the annual survey of the vessel. Procedures for management of change and relevant change records shall be made available at the time of survey. In the cases where the change requires approval from ISC up front, the relevant procedures and documentation for the change in question may be verified at that time. During newbuilding, the verification of management of change in the newbuilding phase is divided into two:
(1) Procedures are verified as a part of the verification of the quality management system (Table 2.6.6.2);
(2) Project specific implementation of the procedures are verified during FAT and after FAT.

2.6.11 Technical requirements on computer-based systems
2.6.11.1 The system shall provide means to identify its name, version, identifier, and manufacturer. It is recommended that the system can automatically report the status of its software to a ship software logging system (SSLS) as specified in the international standard ISO 24060.
2.6.11.2 Loss of a data link shall be specifically addressed in risk assessment analysis/FMEA, including:
(1) A single failure in data link shall not cause loss of vessel- functions of category III. Any effect of such failures shall meet the principle of fail-to-safe for the vesselfunction(s) being served.
(2) For vessel-functions of category II and III, any loss of functionality in the remote control system shall be compensated for by local/manual means.
(3) The data link shall have means to prevent or cope with excessive communication rates.
(4) Data links shall be self-checking, detecting failures or performance issues on the link itself and data communication failures on nodes connected to the link.
(5) Detected failures shall initiate an alarm.
2.6.11.3 Category III systems shall not use wireless data links unless specifically considered by ISC on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to ISC.
2.6.11.4 Other categories of systems may use wireless data links with the following requirements:
(1) Recognised international wireless communication system protocols shall be employed, incorporating:
① Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
② Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
③ Message encryption. Protection of the confidentiality and or criticality of the data content.
④ Security management. Protection of network assets, prevention of unauthorized access to network assets.
(2) The internal wireless system within the vessel shall comply with the radio frequency and power level

requirements of International Telecommunication Union and flag state requirements.
(3) Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.
(4) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.
2.6.11.5 The implementation of the technical requirements provided in 2.6.11 of this Section is verified as part of the system description, FAT and SAT described above.

Section 7 SENSORS

2.7.1 General requirements

2.7.1.1 The sensors are to give stable and normal operational performance over a long period of time. The measuring range and frequency characteristics (if applicable) of sensors are to be consistent with the expected maximum variation range and variation of velocity of the parameters being detected. The sensors are to possess suitable accuracy and sensitivity.
2.7.1.2 The sensors are to have good compatibility with the environmental conditions at their positions. The sensors are to be mechanically robust and durable, having good mechanical protection, reliable electrical connections and good insulated property.
2.7.1.3 The sensors are to be so sited that they can properly reflect the monitored parameters and are readily accessible for testing and renewal. In order that maintenance and renewal can be carried out easily, a protective cover is to be fitted for sensors. Where the sensors are sited in positions inaccessible for renewal, a standby sensor is to be fitted.
2.7.1.4 An independent sensor is to be provided for Mode a protective action; if not specially required, for Mode b protective action, the use of a common sensor with display and alarm is permitted; for Mode c protective action, the use of a common sensor with alarm is permitted.

Section 8 MAIN PROPULSION MACHINERY REMOTELY CONTROLLED FROM NAVIGATION BRIDGE

2.8.1 General requirements

2.8.1.1 If main propulsion machinery is remotely controlled from navigation bridge, the requirements of 2.8.1.2 to 2.8.1.12 of this Chapter are to be complied with.
2.8.1.2 Under all sailing conditions, including manoeuvring, the speed and direction of main propulsion machinery and, if applicable, pitch of the propeller are to be fully controllable from the navigating bridge.
2.8.1.3 The remote control of main propulsion machinery from navigation bridge is to be performed by a single control device for each independent propeller, with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propelling machinery. Where multiple propellers are designed to operate simultaneously, they may be controlled by one control device.
2.8.1.4 The bridge control system is to be independent from the other transmission system, however, one control lever for both system may be accepted.
2.8.1.5 Operations following any setting of the bridge control device including reversing from the maximum ahead service speed in case of emergency are to take place in an automatic sequence and with time intervals acceptable to the machinery.
2.8.1.6 The main propulsion machinery is to be provided with an emergency stopping device on the navigating bridge and independent from the bridge control system, but its actuating unit may not be independent and the arrangement of which is to be such as to preclude inadvertent operation.
2.8.1.7 Main propulsion machinery orders from the navigation bridge are to be indicated in the engine room centralized control station (if fitted) or at the main propulsion machinery local control station.
2.8.1.8 Remote starting of the propulsion machinery is to be automatically inhibited if conditions exist which may hazard the machinery, e.g. shaft turning gear engaged, drop of lubricating oil pressure.
2.8.1.9 The design of the bridge control system is to be such that in case of its failure, an alarm is given. In this case, the speed and direction of the propeller thrust is to be maintained until local control is in

operation, unless this is considered impracticable. In particular, lack of power (electric, pneumatic, hydraulic) is not to lead to major and sudden change in propulsion power or direction of propeller rotation.

2.8.1.10 An alarm is to be provided on the navigation bridge and in the machinery space to indicate low starting air pressure which is to be set at a level to permit further main propulsion machinery starting operations. If the remote control system of the main propulsion machinery is designed for automatic starting, the number of automatic consecutive is to be limited to not more than 3. Visual and audible alarms are to be given on the navigation bridge at the third failure.

2.8.1.11 Bridge control station is to indicate:

(1) main engine speed or propeller speed;

(2) the direction of rotation of fixed pitch propellers or the blade angle (or the pitch) for controllable pitch propellers;

(3) clutch position and shaft brake position (where applicable);

(4) the control station in control;

(5) the power supply to control and monitoring systems relating to the bridge control station.

2.8.1.12 If main propulsion machinery is remotely controlled from navigation bridge, automation systems are to be designed in a manner which ensures that threshold warning of impending or imminent shutdown or shutdown of the main propulsion machinery is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems are to control, monitor, report, alert and take safety action to slow down or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene (such as overriding), except for those cases where manual intervention will result in total failure of the engine and/or main propulsion machinery within a short time, for example in the case of overspeed.

CHAPTER 3 REQUIREMENTS FOR CLASS NOTATION AUT-0 OF PERIODICALLY UNATTENDED MACHINERY SPACES

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to ships of which the main propulsion machinery is remotely controlled from the BCS and the machinery space including ISC is periodically unattended. In this connection, the class notation is AUT-0.

3.1.1.2 Ships with the class notation AUT-0 are, in addition to complying with the requirements of this Chapter, to be in compliance with the requirements of Chapters 1 and 2 of this PART.

3.1.1.3 For passenger ships with the class notation AUT-0, attention is to be paid to the requirements of the flag Administration, if any.

3.1.1.4 In the unattended period, automated systems are to ensure the normal continuous operation of the following machinery and electrical equipment:

(1) main propulsion machinery, including main engines (such as main diesel engine, main steam turbine, main gas turbine and electric propulsion installations), gearing (including clutches and reduction gearboxes) and propellers (including controllable pitch propellers);

(2) essential auxiliary machinery serving the main propulsion machinery;

(3) main and auxiliary boilers;

(4) electric generating plant;

(5) other machinery and electrical equipment, such as air compressors, bilge systems (including oily water separators), valves associated with remote control, fuel oil systems as well as others of which automated control and monitoring is deemed necessary by ISC.

Section 2 MAIN PROPULSION MACHINERY

3.2.1 General requirements

3.2.1.1 The starting, speed regulating, reversing (including shaft reversing) and stopping of the main propulsion machinery are to be capable of being remotely controlled or automatically, sequentially controlled from the ISC. In the case of failure of any part of the control systems, it is to be possible for the main propulsion machinery to be manually controlled from the LCS with regard to the above-mentioned operations.

3.2.2 Main diesel engines

3.2.2.1 The main diesel engines are to comply with the relevant requirements of Chapter 9, PART THREE of the Rules.

3.2.2.2 The control systems of main diesel engines are to comply with the following requirements:

(1) The control system is to ensure that under all operational conditions the engines and shafting will not be subjected to detrimental mechanical and thermal overloads.

(2) The automatic sequential control of main diesel engines is to be provided with necessary interlocks so as to prevent any mechanical damage.

(3) The number of unsuccessful automatic consecutive starts of main diesel engines is not to be more than 3. The main engine is to stop starting at the third failure, and an audible and visual alarm is to be given and the single alarm is to be extended to the BCS.

(4) The control system of main diesel engines is to be so designed that a critical speed range will be automatically crossed over promptly.

(5) Where the main diesel engine is used for main propulsion, means are to be provided to keep the starting air pressure within the required pressure range.

3.2.2.3 The safety system of main diesel engines is to comply with the following:

(1) Safeguards

① A suitable alarm is to be activated at the starting of standby pumps for which the automatic starting is required.

② If an overriding function of the required automatic reduction of power is provided, means are to be provided to preclude inadvertent operation of the overriding function, and a suitable alarm is to be

activated by the operation.

③ If an overriding function of the required automatic stops is provided (with the exception of overspeed), means are to be provided to preclude inadvertent operation of the overriding function, and a suitable alarm is to be activated by the operation. When the main engine is stopped automatically, restarting after restoration of normal operating conditions is to be possible only after manual reset, e.g. by-passing the control lever through the 'stop' position. Otherwise, automatic restarting is not permissible.

(2) For the requirements for the safety system of main diesel engines, refer to column 4 of Table 3.10.1.1 of this Chapter.

(3) In addition, emergency shutdown devices are to be provided at the BCS and ISC (see also 2.8.1.6 of this PART and 3.7.3.5 of this Chapter).

3.2.2.4 The alarm system (including displays) of main diesel engines is to satisfy the following requirements:

(1) Remote indications required in Table 3.10.1.1 of this Chapter are only for items to be displayed and alarmed at the ISC, see columns 2 and 3 of that Table.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.2.5 Where vibration dampers are fitted for main engines:

For torsional or axial vibration dampers oiled by circulating lubrication from main engines and based on amortization thereof, the requirements for the items to be automatically controlled and monitored are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.2.3 Main steam turbines

3.2.3.1 The main steam turbines are to comply with the relevant requirements of Chapter 7, PART THREE of the Rules.

3.2.3.2 The control system of main steam turbines is to comply with the following requirements.

(1) Means are to be provided, by automatic steam spinning, to prevent the risk of thermal distortion of the main steam turbine, when the shaft has been stopped for a period exceeding the predetermined time in the maneuvering mode. However, device capable of stopping such automatic spinning is to be provided in the bridge.

(2) The control system is to be so designed that a critical speed range will be automatically crossed over promptly. Or alternatively, audible and visual alarms are to be given automatically when the turbine is running in the critical speed range, so as to warn the man-on-watch to cross over the critical speed range by manual control.

3.2.3.3 For the requirements for the safety system of main steam turbines, refer to column 4 of Table 3.10.1.1 of this Chapter.

3.2.3.4 The alarm system (including displays) of main steam turbines is to comply with the following requirements.

(1) For items to be displayed and alarmed at the ISC, refer to columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.4 Main gas turbines

3.2.4.1 The main gas turbines are to comply with the relevant requirements of Chapter 8, PART THREE of the Rules.

3.2.4.2 The control system of main gas turbines is to comply with the following requirements.

(1) When the gas turbine increases power from starting to rated condition or decreases power from rated condition to stop running, provision is to be made so that dangerous thermal and/or mechanical stresses will not occur in any part of the turbine due to the control of oil fuel supply, except in case of emergency control. Gas turbine remote control systems are to be so designed that the turbine exhaust gas temperature and the rotor speed can be maintained within a predetermined range and that the combustion in combustion chamber can be maintained in a steady state under normal operations.

(2) The remote control system of gas turbines is to be so designed that the lubricating oil system, oil fuel system and cooling system are interlocked as appropriate in order that the starting and stop of gas turbine operation can be carried out according to the predetermined procedure with sequential control complying with the following requirements:

① the lubricating oil pumps are to be kept in operation both before starting and after stopping the gas turbine. However, special consideration may be given to gas turbines fitted with roller bearings and attached lubricating oil pumps;

② the combustion chambers are to be sufficiently purged with air before ignition;

③ main oil fuel valves are not to open prior to ignition spark;

④ the ignition of each burner is not to exceed the predetermined duration. And if the gas turbine cannot achieve starting within the predetermined period, it is not to repeat the starting;

⑤ no excessive fuel is to be supplied into the combustion chamber during ignition.

(3) The remote control system for single-screw multi-turbine unit is to be so designed that the load on each turbine will not be abnormally distributed.

3.2.4.3 For the requirements for the safety system of main gas turbines, refer to column 4 of Table 3.10.1.1 of this Chapter.

3.2.4.4 The alarm system (including displays) of main gas turbines is to comply with the following requirements:

(1) For items to be displayed and alarmed at the ISC, refer to columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.5 Controllable pitch propellers

3.2.5.1 Controllable pitch propellers are to comply with the relevant requirements in Section 3, Chapter 11, PART THREE of the Rules.

3.2.5.2 Blade angle (or pitch) is to be capable of being remotely controlled or automatically, sequentially controlled from the BCS.

3.2.5.3 The remote control is to be performed by a single control device for each independent propeller, with automatic performance of all associated services. The control of a multi-propeller system where the propellers will possibly be in operation simultaneously may be performed by one device.

3.2.5.4 The combined control system of main engines and controllable pitch propeller for main propulsion is to be capable of preventing the engines and shafting from being overloaded and stopped due to overloading or overspeed.

3.2.5.5 For the hydraulic remote control system of controllable pitch propellers for main propulsion, a standby power source is to be provided. The standby pump supplying hydraulic power for pitch control is to be capable of automatically starting when the pressure of the hydraulic system is below the predetermined value.

3.2.5.6 The blade angle (or pitch) and shaft speed of controllable pitch propellers is to be indicated at each control station from which it is possible to control the propeller pitch (see 2.8.1.11, Chapter 2 and Table 3.10.1.1 of this PART).

3.2.5.7 For the items to be alarmed with regard to controllable pitch propellers, refer to Table 3.10.1.1 of this Chapter.

3.2.6 Electric propulsion installations

3.2.6.1 The function of control and monitoring of the electric propulsion installations is to comply with the requirements in Section 2, Chapter 15, PART EIGHT of the Rules.

3.2.6.2 The electric propulsion installations are to be capable of being controlled at the BCS, and there are to be provided with instruments for indicating the direction of rotation and speed of the propeller shaft, as well as those for indicating other necessary operational parameters.

3.2.7 Clutches

3.2.7.1 The requirements for the items to be automatically controlled and monitored for clutches are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.2.8 Gearboxes

3.2.8.1 The requirements for items to be automatically controlled and monitored for gearboxes are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

Section 3 BOILERS

3.3.1 Main boilers

3.3.1.1 The main boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.

3.3.1.2 The control system of main boilers is to comply with the following requirements.

(1) Water level control

① The automatic control system is to ensure that the boiler water level is maintained within the predetermined range under all working conditions.

② Each boiler is to be provided with two independent low-water-level sensors (one of which is used in the safety system to detect the limited low water level) and one high-water-level sensor. Water level sensors are to be so located as to prevent the release of malfunction signals due to the rolling and pitching of the ship.

(2) Combustion control

① The automatic combustion control system is to be capable of maintaining the predetermined amount of steam generation, steam pressure, steam temperature and a stable combustion of the main steam turbine under all working conditions.

② The sequentially controlled boilers with an automatic ignition system are to satisfy the following requirements:

(a) prior to the initial ignition of the burner, the combustion chamber and flue passes are to be prepurged. The purging time is to be appropriate to a minimum of four air changes in the combustion chamber and flue passes. During boiler purge, the air registers and dampers are to be kept widely open;

(b) ignition can only be initiated after the air entry into and on completion of prepurging of the combustion chamber. The burner fuel valves are not to open prior to ignition spark. In the event of ignition failure, the ignition devices and burner fuel supply valves are to be automatically shut off. The time from fuel supply valve opening to closing is not to be greater than 15 s;

(c) each burner is to be fitted with a flame scanner designed to automatically shut off the fuel oil supply valve in the event of flame failure, and the action of shutoff is to be capable of closing the valve within 6 s following the flameout.

3.3.1.3 The safety system of main boilers:

(1) Where any one of the following faults takes place, the boiler fuel oil supply is to be automatically shut off, or alternatively, equivalent means are to be adopted for the emergency shutdown of the boiler:

① flame failure (i.e. flameout on all burners) in the combustion chamber or ignition failure;

② the water level in the boiler is below the limited low water level (the limited low water level is not to be lower than the lowest permissible water level or the level visible in the gauge glass);

③ loss of the pressure of combustion air in the forced draft to boiler.

(2) In addition to those mentioned in (1) above, separate emergency manual shutoff devices for each boiler fuel oil supply are to be provided at ISC (see also 3.7.3.5 of this Chapter).

(3) The standby pumps for boiler fuel oil are to start automatically when the discharge pressure from the working pumps falls below a predetermined value.

(4) The standby pumps for boiler feed water are to start automatically when the pressure or flow rate from the working pumps falls below a predetermined value.

3.3.1.4 The alarm system of main boilers (including displays)

(1) The items to be displayed and alarmed at the ISC are indicated in columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) The items to be alarmed and the mode of alarms at the BCS are indicated in column 5 of Table 3.10.1.1 of this Chapter.

3.3.2 Auxiliary boilers

3.3.2.1 Auxiliary boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.

3.3.2.2 The combustion control of auxiliary boilers is in general to comply with the requirements of 3.3.1.2(2) of this Section.

3.3.2.3 The safety system of auxiliary boilers is to comply with the requirements of 3.3.1.3(1), 3.3.1.3(2) and 3.3.1.3(3) of this Section. And the standby pumps for boiler feed water are to be started and put into service automatically in case the water level in the boiler is lower than the predetermined value.

3.3.2.4 The items to be automatically controlled and monitored for auxiliary boilers are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.3.3 Exhaust gas boilers

3.3.3.1 Exhaust gas boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.
3.3.3.2 The items to be automatically controlled and monitored for exhaust gas boilers are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.
3.3.3.3 Indicating lights for the operation of boiler water pumps are to be provided at the ISC.
3.3.3.4 It is to be ensured that the safety system of exhaust gas boilers is capable of starting the action of by-pass of exhaust gas or the mechanism of vapour release in case steam drum outlet pressure/temperature of steam boilers is excessively high.

3.3.4 Thermal oil heaters

3.3.4.1 The thermal oil heaters are to comply with the relevant requirements in Section 8, Chapter 4, PART THREE of the Rules.
3.3.4.2 The items to be automatically controlled and monitored for thermal oil heaters are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.
3.3.4.3 The standby pumps are to be started automatically when outlet pressure of circulating pumps for transfer of fuel oil is lower than the predetermined value.
3.3.4.4 For ensuring stable working conditions throughout the operating range of the heater, automatic control is to be provided for the following:
(1) combustion system;
(2) temperature or viscosity of fuel oil (only for heavy oil);
(3) temperature of thermal oil.

Section 4 ELECTRIC GENERATING PLANT

3.4.1 General requirements

3.4.1.1 In addition to complying with the requirements of this Section, the electric generating plant is to be in compliance with the relevant requirements of Chapter 2, PART FOUR of the Rules.
3.4.1.2 The items to be automatically controlled and monitored for electric generating plant are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.4.2 Continuity of power supply

3.4.2.1 Where electrical power is normally supplied by one generating set, arrangements, such as load shedding referred to in 3.4.2.6 of this Section or automatic starting of a standby generating set, etc. are to be provided to ensure that the safety of the ship under all sailing conditions, including maneuvering, is at least equivalent to that of a ship having the machinery space manned.
3.4.2.2 If the electrical power is normally supplied by more than one generator operating in parallel, provision is to be made by means such as load shedding referred to in 3.4.2.6 of this Section, or by appropriate separation of the switchboard bus-bars to ensure that, in the event of loss of one of the generating sets, the remaining set(s) are kept in operation without overload to permit propulsion and steering, and to ensure the safety of the ship.
3.4.2.3 In the event of a failure of the generating set in service, a standby generating set is to be capable of automatically starting and connecting to the main switchboard, with a sufficient capacity to supply those services necessary to ensure that the safety of the ship under all sailing conditions, including maneuvering, is at least equivalent to that of a ship having the machinery spaces manned.
3.4.2.4 All motor-driven essential auxiliaries serving the main propulsion machinery are to be capable of automatically re-starting in a sequence upon restoration of power after interruption.
3.4.2.5 The automatic starting system and characteristics of the standby generating set are to be such as to permit the standby generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum period of 45 s.
3.4.2.6 For the safety of power supply to essential services, suitable load shedding devices are to be provided to automatically cut off the non-essential loads:
(1) when the total load exceeds the rated output power of generator caused by automatic switch-on of additional loads;
(2) when the total load exceeds the sum of rated powers of other generating sets which are still in service in case of the failure of one of generators as more than one generating sets are operating in parallel.

Section 5 AUXILIARY MACHINERY

3.5.1 General requirements

3.5.1.1 The auxiliary machinery referred to in this Section means the prime mover of electric generators, all kinds of pumps and air compressors serving the main propulsion machinery, etc.

3.5.1.2 During the unattended period of machinery spaces, all the auxiliary machinery are to be capable of being normally operated automatically.

3.5.2 Auxiliary diesel engines

3.5.2.1 The items to be automatically controlled and monitored for the auxiliary diesel engines are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.5.3 Pumps

3.5.3.1 The motor-driven pumps serving the main propulsion machinery are to be capable of being automatically started in sequence upon restoration of power after interruption. For the requirements for automatic changeover of standby pumps, see items marked with "c" in column 4 of Table 3.10.1.1 of this Chapter.

3.5.4 Air compressors

3.5.4.1 The items to be automatically controlled and monitored for air compressors are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

Section 6 OTHER EQUIPMENT

3.6.1 Bearings of tail pipes

3.6.1.1 The items to be automatically controlled and monitored for bearings of tail pipes are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.6.2 Valves

3.6.2.1 The valves covered by this Section mean the valves used in bilge and sea water systems (including ballast water system).

3.6.2.2 Failure of actuator power is not to put the valve and the whole ship to an unsafe condition.

3.6.2.3 Positive indication is to be provided at the station for valve control to show the actual valve position or alternatively, whether the valve is fully open or closed.

3.6.2.4 Operating equipment located in places which may be flooded is to be capable of normal operation when submerged.

3.6.2.5 In the event of a failure of the remote or automatic control the valves are to be capable of being operated manually.

3.6.3 Oil purifiers, etc.

3.6.3.1 The items to be automatically controlled and monitored for oil purifiers, oil return tanks of main and auxiliary engines and incinerators are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.6.4 Oil tanks

3.6.4.1 The capacities of fuel oil daily service and settling tanks are to be appropriate to the consumption necessary for the unattended period (such as 8 h, 16 h, 24 h) plus 10% at least. A low level alarm is to be provided for the daily service fuel oil tanks (see Table 3.10.1.1 of this Chapter) and high and low level alarms are to be provided for the settling tanks.

3.6.4.2 Where the daily service fuel oil tanks are replenished automatically or remotely, means are to be provided to eliminate the possibility of overflow, and high and low level alarms are to be provided and extended to the BCS. In this case, the tanks may be exempted from the requirements for capacity as specified in 3.6.4.1 above.

Section 7 ADDITIONAL REQUIREMENTS FOR CONTROL STATIONS (ROOMS)

3.7.1 Provision of control stations (rooms)

3.7.1.1 Bridge control station (BCS), engine room centralized control station (ISC) and local control stations (LCS) are in general to be provided on ships with machinery spaces periodically unattended.

3.7.2 Functions of bridge control stations (BCS)

3.7.2.1 Under all sailing conditions including maneuvering, the speed and direction of thrust of main propulsion machinery as well as other associated installations (if fitted) are to be effectively controlled from the BCS. When necessary, the control is to be capable of being changed over to other control stations at any time and the changeover is to comply with the relevant requirements of 2.5.2 of this PART. The design and arrangement of bridge control station are to comply with the requirements in Section 8, Chapter 2 of this PART.

3.7.2.2 Alarms at the BCS

(1) For the items to be alarmed at the BCS and the mode of alarms, see column 5 of Table 3.10.1.1 of this Chapter. Alarms indicating the faults in the machinery and electrical equipment as well as the automated control and monitoring systems are, in general, to be relayed to the BCS in the following modes: group alarms for the protective actions of safety systems; separate alarms; group alarms for serious faults and group alarms for general faults.

(2) The audible alarms at the BCS are permitted to be silenced after acknowledgment, but the visual alarms are to be extinguished only after the rectification of faults, and furthermore, the visual signals are to be capable of being clearly distinguishable before and after acknowledgment.

3.7.2.3 If the main engine is remotely started from the bridge control station, the indicator is to be fitted on the bridge control station for the starting air pressure or voltage of starting storage batteries of main engines.

3.7.3 Functions of centralized control stations (rooms) of engine room (ISC)

3.7.3.1 The ISC is to be capable of performing functions of control and changeover of the main propulsion machinery as specified in 3.7.2.1 of this Section, and besides, it is also to be capable of controlling and monitoring the other equipment as specified in 3.1.1.4 of this Chapter.

3.7.3.2 Instruments or display units are to be provided at the ISC to indicate the essential parameters for ensuring the safe and reliable operation of the machinery and electrical equipment. The items to be displayed are given in column 2 of Table 3.10.1.1of this Chapter.

3.7.3.3 All faults including several faults occurred at the same time in the machinery and electrical equipment and in the control and monitoring systems are to be capable of being alarmed at the ISC. The items to be alarmed are given in column 3 of Table 3.10.1.1of this Chapter.

3.7.3.4 Audible alarms at the ISC are to be capable of being silenced only after being acknowledged at the station.

3.7.3.5 The emergency button for stopping main propulsion machinery and the emergency buttons for cutting off oil supply to boilers and incinerators provided at the ISC are to be independent of the automated systems of the station, but their actuating units may not be required to be independent and are to be arranged so as to preclude inadvertent operation.

3.7.3.6 Where overriding function as prescribed in 1.1.2.1(9) of this PART is provided for main engines, the overriding function is also to be provided at the ISC, and is to be so arranged as to preclude inadvertent operation.

3.7.4 Functions of local control stations (LCS)

3.7.4.1 The LCS is to comply with the requirements of 2.5.1.5 of this PART.

3.7.5 Communication

3.7.5.1 In addition to complying with the relevant requirements of PARTs THREE and FOUR of the Rules, reliable means of vocal communication are to be provided between the ISC or the LCS (if applicable), the BCS and the engineers' accommodation.

Section 8 ADDITIONAL REQUIREMENTS FOR CONTROL AND MONITORING SYSTEMS

3.8.1 Safety systems

3.8.1.1 The safety systems in all controlled and monitored machinery and electrical equipment are to be in compliance with the requirements of Section 3, Chapter 2 of this PART.

3.8.2 Alarm systems

3.8.2.1 The arrangement of the alarm display is to assist in identifying the particular fault condition and its location within the machinery space.

3.8.2.2 If the bridge navigating officer of the watch is the sole watch-keeper then, in the event of a machinery fault being monitored at the control location for machinery, the alarm system is to be such that this watch-keeper is made aware when:

(1) a machinery fault has occurred;

(2) the machinery fault is being attended to (e.g. acknowledging, silencing);

(3) the machinery fault has been rectified. Alternative means of communication between the bridge area, the accommodation for engineering personnel and the machinery spaces (ISC or local control stations) may be used for this function.

3.8.2.3 Group alarms may be arranged on the bridge to indicate machinery faults. Alarms associated with faults requiring speed reduction or automatic shutdown of propulsion machinery are to be separately identified (see column 5 in Table 3.10.1.1 of this Chapter).

3.8.2.4 The alarm system is to be capable of being tested during normal machinery operation. Where practicable, means are to be provided at convenient and accessible positions to permit the sensors to be tested without affecting the operation of the machinery.

3.8.2.5 If an alarm has been acknowledged and a second fault occurs before the first is rectified, then audible and visual alarms are to operate again. Alarms due to temporary failures are to remain activated until acknowledged.

3.8.2.6 Automatic recording devices are to be provided at the ISC for recording the important parameters and faults. Where a computer system is used, its recording device may be adopted instead.

3.8.2.7 A changeover switch is to be provided to relay all the fault alarms to the engineers' accommodation and each engineer's cabin by group alarms so as to ensure that the alarm signal is relayed at least to one cabin of the engineer on watch.

Acknowledgment of alarms at positions outside a machinery space (including the ISC) is not to silence the audible alarm or extinguish the visual alarm in that machinery space (including the ISC).

Where an alarm has not been acknowledged in a certain time (not more than 5 min) in the machinery space (including the ISC), the alarm system referred to in 2.8.4 of Chapter 2, PART FOUR of the Rules is to be activated automatically, and the alarm is to be clearly audible within the engineers' accommodation and related public spaces.

Section 9 FIRE PRECAUTIONS AND PROTECTION AGAINST FLOODING

3.9.1 Fire precautions

3.9.1.1 The fire precautions for periodically unattended machinery spaces (including the ISC) are to comply with the relevant requirements of PART SIX of the Rules, inter alia, the requirements for the special arrangements in machinery spaces, fire detection and alarm systems, and water fire-extinguishing systems. There is to be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigating bridge or fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that this requirement need not be complied with for cargo ships of less than 1,600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position.

3.9.1.2 In addition to complying with the requirements for engine rooms given in PART THREE of the Rules, the fire precautions for periodically unattended machinery spaces are to comply with the following.

(1) Fuel oil, lubricating oil and hydraulic oil pipelines are to be so constructed and arranged as to avoid excessive stresses due to vibration and expansion. Flange joints are to be minimized as far as practicable in the above pipelines.

(2) Equipment for the automatic treatment of flammable oils, such as oil purifiers, oil heaters, oil filters, oil pumps, etc., are to be provided with means to prevent oil spillage, for instance, drip trays fitted below the equipment for collecting oil leakage and draining it to a sludge tank. The above-mentioned equipment is to be centralized as far as practicable in a special space.
(3) The high pressure fuel oil pipelines are to be screened or otherwise suitably protected to prevent leaks from dripping or spraying onto hot surfaces or into machinery air intakes, for instance, the fitting of metal sheathing to the high pressure fuel injection pipes of diesel engines.
(4) Leakage from high pressure fuel pipes are to be, as far as practicable, collected and led to a collector tank(s) fitted in a safe position and arrangements are to be provided for an alarm to be given in the event of leakage, see Table 3.10.1.1 of this Chapter.
(5) Fuel oil or lubricating oil heaters are to comply with the following:

① high temperature alarm or low flow alarm is to be provided unless it is impossible to reach the ignition temperature of medium;

② in addition to the temperature control, an independent safeguard is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating media remains limited to a value below 220℃;

③ where electric heaters are adopted, an independent safeguard is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures, except that all live heating components are soaked in oil and the surface temperature of the heating components remains below 220℃.

3.9.1.3 Special requirements for fire detection systems
(1) An automatic fire detection system is to be fitted in the machinery spaces.
(2) The system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm.
(3) The fire detection indicating panel is to be located on the navigation bridge, fire control station, or other accessible place where a fire in the machinery space will not render it inoperative.
(4) The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other audible signals are to be audible throughout the navigation bridge and the accommodation area of the personnel responsible for the operation of the machinery space.
(5) Fire detectors are to be of such types, and so located, that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to comply with the relevant requirements of the International Convention for the Safety of Life at Sea, 1974 (hereinafter referred to as SOLAS Convention) and the International Code for Fire Safety Systems (hereinafter referred to as FSS Code) as well as ISC rules. A combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.
(6) Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement of the fire detection system, the number of loops and the location of detector heads are to be approved in each case and comply with the relevant requirements of SOLAS Convention and FSS Code. Air currents created by the machinery are not to render the detection system ineffective.
(7) When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be ensured to fix and identify the set point.
(8) When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a preset time.
(9) The fire detection indicating panel is to be provided with facilities for functional testing.
(10) The fire detection system is to be fed automatically from the emergency source of power by separate feeder if the main source of power fails, and to comply with the requirements of 2.9.6, PART FOUR of the Rules.
(11) Facilities are to be provided in the fire detection system to release manually the fire alarm from the passageways having entrances to engine and boiler rooms, navigation bridge and control station in engine room.
(12) The fire detection system is to be tested upon installation on board to confirm compliance with the rule requirements for function.

3.9.2 Protection against flooding

3.9.2.1 An alarm system is to be provided to warn high bilge water level in machinery spaces. The alarm level is to be sufficiently low to prevent liquid overflowing from the bilge onto the tank top of double bottom tanks.
3.9.2.2 The number and location of bilge water level detectors are to be such as to prevent false alarms at normal angles of trim and heel.
3.9.2.3 The location of the controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system, for controlling flooding upon damage, is to be such as to allow adequate time for operation in case of influx of water to the space, having regard to at least 10 min which could be required to reach and close the valve. Arrangements are to be made to operate the controls from a position above the level to which the space could become flooded due to any broken pipe with the ship being in the fully loaded condition.
3.9.2.4 Bilge wells are to be large enough to accommodate normal drainage during the unattended period. Where the bilge pumps are arranged to start automatically, smaller bilge wells may be permitted to accommodate the normal drainage for a suitable time, provided that an alarm is provided to indicate if the influx of liquid is greater than the pump capacity or if the pump is operating more frequently than would normally be expected and that the discharge complies with the relevant requirements for pollution prevention. The items to be controlled and monitored are indicated in Table 3.10.1.1 of this Chapter as appropriate.
3.9.2.5 Alarms required by 3.9.2.1 and 3.9.2.4 above are to be given at the ISC, BCS and engineers' accommodation area.

Section 10 AUTOMATIC CONTROL AND MONITORING ITEMS

3.10.1 Table of automatic control and monitoring items

3.10.1.1 The automatic control and monitoring items (if fitted) for all ships with the class notation AUT-0 are to comply with Table 3.10.1.1.
3.10.1.2 The designations used in Table 3.10.1.1 of this Section are defined as follows:

–: not required;
*: only required for trunk piston diesel engines;
a: Mode a protective action, such as emergency shutdown of the engine, fuel oil cutoff of boiler and cutoff of electric power supply, etc.;
b: Mode b protective action, such as reducing the speed of rotation or the output of machinery;
c: Mode c protective action, such as starting and putting into operation of standby pump or standby unit;
S: single alarm;
G_a: group alarm activated by Mode a protective action;
G_b: group alarm activated by Mode b protective action;
R: group alarm for serious faults;
Y: group alarm for general faults.

3.10.1.3 Where "per cylinder" appears in the column "Remark" of Table 3.10.1.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, "fitted on manifold outlet" may be used to replace the "per cylinder".
3.10.1.4 For the equipment marked with "▲" in Table 3.10.1.1 of this Section, if all of the single alarms and display items provided locally or in the vicinity of the engine are confirmed by ISC, the engine room central control station and the BCS may be exempted from the single alarms and display items as required in Table 3.10.1.1. Only one group alarm for general faults and one fault display are to be provided in this case.

Automatic Control and Monitoring Items for Ships with Class Notation AUT-0

Table 3.10.1.1

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
1. Main diesel engine 1.1 Fuel oil system					
Fuel oil inlet pressure	Pressure	Low	c	*R*	Fitted after filter
Fuel oil temperature or viscosity	Temp. or	Low and	–	*Y*	Only for heavy oil

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
(before injection pumps)	viscosity	high			
Leakage from high pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tanks	–	Low	–	*Y*	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	*Y*	
1.2 Lubricating oil system					
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	*R*	
			b	G_b	Necessary for crosshead diesel engines
		Excessively low	a	G_a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	*R*	Required if separate lub-oil system installed for crosshead diesel engines
			b	G_b	
		Excessively low	a	G_a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to camshaft	Temp.	High	–	*Y*	
*Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	Temp.	High	–	*Y*	
Thrust bearing pad temperature or bearing temperature	Temp.	High	b	G_b	Necessary for crosshead diesel engines
		Excessively high	a	G_a	
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	G_b	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	G_a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator (each apparatus)	–	Small	b	G_b	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	*Y*	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	*Y*	
1.3 Turbocharger system					
Turbocharger lub-oil inlet pressure	Pressure	Low	–	*Y*	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp	High	–	*Y*	Where outlet temperature from each bearing cannot be monitored due to the

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
					engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)					
Piston coolant inlet pressure	Pressure	Low	c	*Y*	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	G_b	
Piston coolant outlet flow	–	Low	b	G_b	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	G_b	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	*Y*	
1.5 Seawater cooling system					
Pressure of cooling seawater	Pressure	Low	c	*Y*	
1.6 Cylinder fresh cooling water system					
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	*Y*	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	G_b	
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temp.	High	b	G_b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
1.7 Starting and control air systems					
Starting air pressure before main shut-off valve	Pressure	Low	–	*S*	
Control air pressure	Pressure	Low	–	*S*	
Safety air pressure	Pressure	Low	–	*S*	Necessary for crosshead diesel engines
1.8 Scavenge air system					
Scavenge air receiver pressure	Pressure	–	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temp.	High	b	G_b	
Scavenge air receiver water level	–	High	–	*Y*	

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
*Scavenge air receiver temperature	Temp.	High	–	*Y*	
1.9 Exhaust gas system					
Exhaust gas temp. after each cylinder	Temp.	High	b	G_b	For trunk piston diesel engines having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	*R*	
Exhaust gas temperature before each turbocharger	Temp.	High	–	*R*	Necessary for crosshead diesel engines
Exhaust gas temperature after each turbocharger	Temp.	High	–	*R*	
1.10 Fuel valve coolant					
Pressure of fuel valve coolant	Pressure	Low	c	*R*	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temp.	High	–	*Y*	
Level of fuel valve coolant in expansion tank	–	Low	–	*Y*	
1.11 Engine speed/direction of rotation					
Speed	Speed	Overspeed	a	G_a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	*S*	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
2 Auxiliary diesel engines▲					
Lub-oil inlet pressure	Pressure	Low	–	*Y*	
		Excessively low	a		
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For engine power > 500 kW per cylinder only
Lub-oil inlet temperature	–	High	–	*Y*	
Temperature of cooling water or cooling air outlet	Temp.	High	–	*Y*	
Pressure or flow of cooling water	–	Low	–	*Y*	
Speed	–	Overspeed	a	*Y*	See 9.7.10.3 of Pt.3
Starting air pressure	Pressure	Low	–	*Y*	
Fuel oil leakage from pressure pipes	–	Leakage	–	*Y*	
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	*Y*	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Level in fuel oil daily service tank	–	Low	–	*Y*	
Level in cooling water expansion tank	–	Low	–	*Y*	If not connected to main system
Common rail fuel oil pressure	–	Low	–	*Y*	
Common rail servo oil pressure	–	Low	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Power supply for control-safety-alarm systems	Electrical, pneumatic	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
(electrical, pneumatic and hydraulic pressure)	and hydraulic pressure				
3 Electric generating plant▲					
Bus bar voltage	Voltage	High and low	–	*Y*	
Bus bar frequency	Frequency	High and low	–	*Y*	
Load shedding	–	When in operation	–	*Y*	
Automatic switch-on of circuit breaker	–	Failure	–	*Y*	
Tripping of automatic circuit breaker	–	When in operation	–	*Y*	
Failure of load distribution	–	Failure		*Y*	Fitted if automatic load distribution is adopted
4 Main gas turbines					
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	c	*Y*	
Oil level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Turbine main bearing temperature	Temp.	High	–	*Y*	
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	*Y*	
Level in fuel oil daily service tank	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temp.	High	–	*Y*	
		Excessively high	a	G_a	
Deviation of exhaust gas temperature from average	–	High	–	*Y*	
Gas turbine combustion chamber flame and ignition	–	Failure	a	G_a	
Gas turbine vibration	–	High	–	*Y*	
		Excessively high	a	G_a	
Axial displacement of turbine rotor	–	Great	–	*R*	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
5 Auxiliary gas turbines▲					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a		
Exhaust gas temperature	Temp.	High	a	*Y*	
Combustion chamber flame	–	Extinguished	a	*Y*	
Gas turbine vibration	–	Excessive	a	*Y*	

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Gas turbine speed	–	Overspeed	a	*Y*	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
6 Main steam turbines					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature for turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level of lub-oil tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temp.	High	–	*Y*	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	*Y*	
Astern turbine exhaust steam temperature	Temp.	High	–	*Y*	
Gland steam pressure	Pressure	High and low	–	*Y*	
Circulating seawater pressure or flow	Pressure or flow	Low	c	*Y*	
Main condenser vacuum	Vacuum	Low	b	G_b	
Main condenser condensate level	–	High and low	b	G_b	
Condensate pump	–	Stop/failure	–	*Y*	
Condensate salinity	–	High	–	*Y*	
Steam turbine vibration	–	Excessive	b	G_b	
Axial displacement of turbine rotor	–	Excessive	a	G_a	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
7 Auxiliary steam turbines▲					
Lub-oil inlet temperature for turbine and gearing	–	High	–	*Y*	
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a		
Condenser vacuum	–	Low	a	*Y*	
Axial displacement of turbine rotor	–	Excessive	a	*Y*	
Turbine speed	–	Overspeed	a	*Y*	
Power supply for control-safety-alarm systems (electric, pneumatic, hydraulic)	Electric, pneumatic and hydraulic pressure	Loss	—	*Y*	Indication of voltage may be replaced by indicating lamp
8 Main steam boilers					
Steam drum or superheater outlet pressure	Pressure	High and low	–	*R*	
Superheated steam outlet temperature	Temp.	High	–	*R*	
De-superheated steam outlet	Temp.	High	–	*R*	

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
temperature					
Boiler feed water level	Level	High	–	*R*	At least 3 sensors fitted. See 3.3.1.2(1)② and 3.3.1.3(1)② of this Chapter
		Low	c	*R*	
		Excessively low	a	G_a	
Temperature or viscosity of oil fuel to burners	Temp. or viscosity	Low and high	–	*Y*	Only for heavy oil Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	G_a	
Fuel oil pressure to burners	Pressure	Low	c	*Y*	See 3.3.1.3(3) of this Chapter
Forced draft pressure	Pressure	Loss	a	G_a	2 sensors fitted
Burner flame and ignition	–	Extinguished / ignition failure	a	G_a	Each burner is to be monitored
Fuel oil atomizing steam (air) pressure	Pressure	Low	–	*Y*	
Feed pump discharge pressure or flow	Pressure or flow	Low	c	*R*	See 3.3.1.3(4) of this Chapter
Feed water forced circulation flow	Flow	Low	a	G_a	Required for forced circulating boilers only
Level of feed water tank	–	Low	–	*Y*	Required for daily feed water tanks only
Feed water salinity	–	High	–	*Y*	
Water level of deaerator	–	High and low	–	*Y*	
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	*Y*	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
9 Auxiliary steam boilers▲					
Steam drum or superheater outlet pressure	Pressure	Low	–	*Y*	
Boiler feed water level	–	High	–	*Y*	See 3.3.2.3, 3.3.1.2(1)② and 3.3.1.3(1)② of this Chapter
		Low	c	*Y*	
		Excessively low	a	*Y*	
Temperature or viscosity of oil fuel to burners	Temp. or viscosity	Low and high	–	*Y*	Only for heavy oil Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	*Y*	
Fuel oil pressure to burners	Pressure	Low	c	*Y*	See 3.3.1.3(3) of this Chapter
Forced draft pressure	–	Loss	a	*Y*	
Burner flame and ignition	–	Extinguished / ignition failure	a	*Y*	
Feed water salinity	–	High	–	*Y*	Only applicable to auxiliary steam boiler for driving turbine-generator set
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	*Y*	
Power supply for	Electrical,	Loss	–	*Y*	Indication of voltage may be

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	pneumatic and hydraulic pressure				replaced by indicating lamp
10 Controllable pitch propeller					
Pitch or blade angle of controllable pitch propeller	Pitch or blade angle	—	—	—	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	—	—	—	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	*S*	
Hydraulic oil tank level	–	Low	–	*Y*	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	*Y*	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	*Y*	
11 Vibration damper					
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	*Y*	See 3.2.2.5 of this Chapter and 12.1.4.3, Ch.12, Pt.3
12 Gearbox (for main propulsion machinery)					
Lub-oil inlet pressure of gearbox	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature of gearbox	Temp.	High	–	*Y*	
Gear oil pressure	Pressure	Low	–	*Y*	
13 Clutches					
Clutch position	Position	–	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	See 2.8.1.11 of this PART
14 Stern tube bearing					
Oil lubricated stern tube bearing temp.	–	High	–	*Y*	
Level of stern tube lubricating oil tank	–	Low	–	*Y*	
15 Exhaust gas boilers					
Circulating feed pump outlet pressure or flow	Pressure or flow	Low	c	*Y*	Only applicable to water tube exhaust gas boiler with forced circulation
Fire in exhaust gas pipelines	–	Fire	–	*Y*	
Steam pressure	Pressure	High	–	*Y*	
16 Air compressors▲					
Air compressor lubricating oil pressure	–	Low	a	*Y*	Except for splash lubrication
17 Thermal oil heaters▲					
(1) Oil-fired					
Thermal oil expansion tank level	–	Low	a	*Y*	
Thermal oil flow or pressure	–	Low	a	*Y*	
Thermal oil outlet temperature	–	High	a	*Y*	
Combustion air pressure or forced ventilation	–	Low or shutoff	a	*Y*	
Fuel oil pressure	—	Excessively low	c	*Y*	
Fuel oil temperature or viscosity	—	Low and high	—	*Y*	Only for heavy oil
Uptake temperature	–	High	a	*Y*	

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Burner flame and ignition	–	Extinguished / ignition failure	a	*Y*	Each burner is to be monitored
(2) Exhaust-fired					
Thermal oil expansion tank level	–	Low	a	*Y*	
Thermal oil flow or pressure	–	Low	a	*Y*	
Thermal oil outlet temperature	–	High	a	*Y*	
Exhaust temperature	–	High	–	*Y*	
18 Computer systems					
Computers under operating status	–	Failure	c	*R*	
Computer systems	–	Failure	–	*R*	Including ineffectiveness of local area network control, overload of local area network, running stop due to overflow, etc.
Electrical power of computer systems	Voltage	Failure	–	*Y*	Indication of voltage may be replaced by indicating lamp
19 Oil purifier▲					
Purifier oil outlet pressure	Pressure	Low	–	*Y*	
Purifier oil inlet temperature	–	High	–	*Y*	
20 Sludge tank					
Level of sludge tank	–	High	–	*Y*	
21 Bilge					
Bilge level	–	High	–	*S*	See 3.9.2.1 of this Chapter
Bilge pumps	Indication for operation time	Too long or more frequently	–	*Y*	For automatically controlled bilge pumps only, see 3.9.2.4 of this Chapter
22 Incinerator▲ (only for unattended operation during incinerating)					
Fuel oil viscosity or temperature	–	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure	–	Low	–	*Y*	
Combustion air pressure	–	Low	a	*Y*	
Burner flame and ignition	–	Extinguished / ignition failure	a	*Y*	
Furnace temperature	–	High	a	*Y*	
Exhaust gas temperature	–	High	–	*Y*	
23 Diesel engines driving propulsion generators					
Fuel oil inlet pressure	Pressure	Low	c	*R*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tank	–	Low	–	*Y*	
Common rail fuel oil pressure	–	Low	–	*Y*	
Common rail servo oil pressure	–	Low	–	*Y*	
Lub-oil inlet pressure	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	–	High	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature	–	High	a	*S*	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
of the above bearing or other equivalent devices)					engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	*Y*	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	c	*R*	
Cylinder cooling water pressure or flow	Pressure or flow	Low	c	*R*	
Cylinder cooling water outlet temperature	Temp.	High	–	*Y*	
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
Starting air pressure	Pressure	Low	–	*S*	
Control air pressure	Pressure	Low	–	*S*	
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	G_a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
24 Gas turbines driving propulsion generators					
Fuel oil pressure or flow	Pressure or flow	Low	c	*R*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Turbine main bearing temperature	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Level in fuel oil tank for ignition and starting	–	Low	–	*S*	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	G_a	
Combustion chamber flame	–	Extinguished	a	G_a	
Exhaust gas temperature	Temp.	High	a	G_a	
Gas turbine vibration	–	Excessive	a	G_a	
Axial displacement of turbine rotor	–	Great	a	G_a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp

Item	ISC		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
	pressure				
25 Low sulphur distillate fuels					
Temperature or viscosity of fuel oil	Temperature or viscosity	High or low	–	*Y*	
Temperature of fuel oil	Temperature	Low	–	*Y*	When a refrigerating system for low sulphur distillate fuels is provided
Level in cooling water expansion tank (if provided) of the fuel oil cooling system	–	Low	–	*Y*	
26 Miscellaneous					
Overriding function	–	When overriding is initiated	–	*S*	
Controlled environmental conditions	–	Abnormal	–	*Y*	Where controlled environment is required for equipment, this requirement is to be complied with
Automatic systems	–	Failure	–	*Y*	Including electric power fault

CHAPTER 4 REQUIREMENTS FOR MACHINERY NOTATIONS OF CONSTANTLY ATTENDED MACHINERY SPACES

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 This Chapter applies to ships with machinery spaces (including the ISC) constantly attended by watch-keepers, and intended to be assigned machinery notations MCC and/or BRC.

4.1.1.2 In addition to this Chapter, ships intended to be assigned the above-mentioned machinery notations are to comply with the applicable requirements of Chapters 1 and 2 of this PART.

Section 2 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION MCC

4.2.1 Provision of control stations (rooms)

4.2.1.1 Ships with the class notation MCC are to be provided with the ISC and the LCS. When the machinery and electrical equipment are in normal operation, the ISC is to be constantly attended by watch-keepers.

4.2.2 Functions of the ISC

4.2.2.1 The control and monitoring functions of the ISC is to be in compliance with the following requirements:

(1) The starting, speed regulating, reversing (including shaft reversing) and stopping as well as blade angle (or pitches) of the main propulsion machinery are to be capable of being remotely controlled or automatically, sequentially controlled from the ISC. When necessary, the control is to be capable of being changed over to other control stations (rooms) at any time and the changeover is to comply with the relevant requirements of 2.5.2 in this PART. In addition, the other machinery and electrical equipment mentioned in 3.1.1.4 of this PART are to be controlled and monitored automatically.

(2) The design and arrangement of centralized control station of engine room are to comply with the following requirements:

① in principle, the remote control from the ISC to main propulsion machinery is to be performed by a single control device for each independent propeller, with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propelling machinery;

② the control system of the ISC is to be independent from the other communication system, however, one control lever for both systems may be accepted;

③ operations following any setting of the ISC including reversing from the maximum ahead service speed in case of emergency are to take place in an automatic sequence and within time intervals acceptable to the machinery;

④ remote starting of the propulsion machinery in the ISC is to be automatically inhibited if conditions exist which may hazard the machinery, e.g., shaft turning gear engaged, drop of lubricating oil pressure;

⑤ the design of the control system in the ISC is to be such that in case of its failure an alarm is given. In this case, the speed and direction of the propeller are to be maintained until local control is in operation, unless this is considered impracticable. In particular, lack of power (electric, pneumatic, hydraulic) or changeover of control is not to lead to major and sudden change in propulsion power or propulsion direction.

(3) Instruments and display units are to be provided at the ISC to indicate the essential parameters for ensuring the safe and reliable operation of the machinery and electrical equipment. The items to be displayed are given in column 2 of Table 4.2.6.1 of this Chapter.

(4) All faults, including several faults occurred at the same time in the machinery and electrical equipment and in the control and monitoring systems are to be capable of being alarmed at the ISC. The items to be alarmed are given in column 3 of Table 4.2.6.1 of this Chapter.

(5) Audible alarms at the ISC are to be capable of being silenced only after being acknowledged at the station.
(6) The emergency button for stopping the main propulsion machinery and the emergency button for cutting off oil supply to boilers are to be provided at the ISC and independent of the control system, but their actuating units may not be independent, and are to be so arranged as to preclude inadvertent touching.
(7) Where overriding function is provided for the main engine, such function is also to be provided at the ISC, and is to be so arranged as to preclude inadvertent touching.

4.2.2.2 The functions of automatic and remote control of all the machinery and electrical equipment specified in 3.1.1.4 of this PART are to be, in general, in compliance with the requirements of Sections 2, 3, 5 and 6 of Chapter 3 of this PART. However, the intervention of some control processes by the attendant in the ISC is permitted, provided that the attendant is competent to perform such control, such as the employment of remote control to substitute some items in the automatic control.

4.2.2.3 For the safety system, Mode a protective action is to be carried out automatically, Modes b and c protective actions may be carried out automatically or by manual operation in the ISC.

4.2.3 Functions of the local control station (LCS)

4.2.3.1 The LCS is to comply with the requirements of 2.5.1.5 of this PART.

4.2.4 Fire precautions

4.2.4.1 The fire precautions are in general to comply with the requirements for fire detection and fire alarm systems in 3.9.1.3 of this PART (the areas of an engine room which can be seen from the ISC may be exempted from the required sensors) and the requirements in 3.9.1.2 (except (4)) of this PART.

4.2.5 Protection against flooding

4.2.5.1 A bilge high level alarm system is to be provided.

4.2.5.2 The overboard discharge of bilge is to comply with the relevant requirements for pollution prevention.

4.2.6 Table of automatic control and monitoring items

4.2.6.1 The automatic control and monitoring items (if fitted) for all ships with the class notation MCC are to comply with Table 4.2.6.1.

4.2.6.2 The designations used in Table 4.2.6.1 of this Section are defined as follows:

−: not required;
*: only required for trunk piston diesel engines;
a: Mode a protective action, such as emergency shutdown of the engine, fuel oil cutoff of boiler and cutoff of electric power supply, etc.;
b: Mode b protective action, such as reducing the speed of rotation or the output of machinery;
c: Mode c protective action, such as starting and putting into operation of standby pump or standby unit.

4.2.6.3 Where "per cylinder" appears in the column "Remark" of Table 4.2.6.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, "fitted on manifold outlet" may be used to replace "per cylinder".

4.2.6.4 For the equipment marked with "▲" in Table 4.2.6.1 of this Section, if all of the single alarms and display items provided locally or in the vicinity of the engine are confirmed by ISC, the engine room central control station may be exempted from the single alarms and display items as required in Table 4.2.6.1. Only one group alarm for general faults and one fault display are to be provided in this case.

Automatic Control and Monitoring Items for Ships with Class Notation MCC

Table 4.2.6.1

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
1 Main diesel engine 1.1 Fuel oil system				
Fuel oil inlet pressure	Pressure	Low	c	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	Only for heavy oil
Leakage from high pressure fuel pipes	–	Leakage	–	

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Level of fuel oil in daily service tanks	–	Low	–	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	
1.2 Lubricating oil system				
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	
			b	Necessary for crosshead diesel engines
		Excessively low	a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	Required if separate lub-oil system installed for crosshead diesel engines
			b	
		Excessively low	a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature to camshaft	Temperature	High	–	
*Lub-oil filter differential pressure	Pressure	Great	–	
Lub-oil inlet temperature	Temperature	High	–	
Thrust bearing pad temperature or bearing temperature	Temperature	High	b	Necessary for crosshead diesel engines
		Excessively high	a	
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	b	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	
1.3 Turbocharger system				
Turbocharger lub-oil inlet pressure	Pressure	Low	–	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp	High	–	Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
				with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative
Speed of turbocharger	Speed	High	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)				
Piston coolant inlet pressure	Pressure	Low	c	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	
Piston coolant outlet flow	–	Low	b	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	
1.5 Seawater cooling system				
Pressure of cooling seawater	Pressure	Low	c	
1.6 Cylinder fresh cooling water system				
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temperature	High	b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	
1.7 Starting and control air systems				
Starting air pressure before main shut-off valve	Pressure	Low	–	
Control air pressure	Pressure	Low	–	
Safety air pressure	Pressure	Low	–	Necessary for crosshead diesel engines
1.8 Scavenge air system				
Scavenge air receiver pressure	Pressure	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temperature	High	b	
Scavenge air receiver water level	–	High	–	
*Scavenge air receiver temperature	Temperature	High	–	
1.9 Exhaust gas system				
Exhaust gas temp. after each cylinder	Temperature	High	b	For trunk piston diesel engines having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	
Exhaust gas temperature before each turbocharger	Temperature	High	–	Necessary for crosshead diesel engines

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Exhaust gas temperature after each turbocharger	Temperature	High	–	
1.10 Fuel valve coolant				
Pressure of fuel valve coolant	Pressure	Low	c	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temperature	High	–	
Level of fuel valve coolant in expansion tank	–	Low	–	
1.11 Engine speed/direction of rotation				
Speed	Speed	Overspeed	a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
2 Auxiliary diesel engines▲				
Lub-oil inlet pressure	Pressure	Low	–	
		Excessively low	a	
Fuel oil temperature or viscosity (before injection pumps)	Temperature or viscosity	Low or high	–	Only for heavy oil
Exhaust gas temp. after each cylinder	Temperature	High	–	For engine power > 500 kW per cylinder only
Lub-oil inlet temperature	–	High	–	
Temperature of cooling water or cooling air outlet	Temperature	High	–	
Pressure or flow of cooling water	–	Low	–	
Speed	–	Overspeed	a	See 9.7.10.3 of Pt.3
Starting air pressure	Pressure	Low	–	
Fuel oil leakage from pressure pipes	–	Leakage	–	
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Level in fuel oil daily service tank	–	Low	–	
Level in cooling water expansion tank	–	Low	–	If not connected to main system
Common rail fuel oil pressure	–	Low	–	
Common rail servo oil pressure	–	Low	–	
Speed of turbocharger	Speed	High	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
3 Main gas turbines				
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature to gas turbine and gearing	Temperature	High	–	

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Lub-oil filter differential pressure	–	Great	c	
Oil level in lub-oil circulating tank	–	Low	–	For gravity and circulating oil tanks
Turbine main bearing temperature	Temperature	High	–	
Coolant pressure or flow	–	Low	–	
Coolant temperature	Temperature	High	–	
Fuel oil temperature or viscosity	Temperature or viscosity	Low or high	–	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	
Level in fuel oil daily service tank	–	Low	–	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temperature	High	–	
		Excessively high	a	
Deviation of exhaust gas temperature from average	–	High	–	
Gas turbine combustion chamber flame and ignition	–	Failure	a	
Gas turbine vibration	–	High	–	
		Excessively high	a	
Axial displacement of turbine rotor	–	Great	–	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
4 Auxiliary steam turbines▲				
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Exhaust gas temperature	Temperature	High	a	
Combustion chamber flame	–	Extinguished	a	
Gas turbine vibration	–	Excessive	a	
Gas turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
5 Main steam turbines				
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature for turbine and gearing	Temperature	High	–	
Lub-oil filter differential pressure	–	Great	–	
Level of lub-oil tank	–	Low	–	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temperature	High	–	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	
Astern turbine exhaust steam temperature	Temperature	High	–	

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Gland steam pressure	Pressure	High and low	–	
Circulating seawater pressure or flow	Pressure or flow	Low	c	
Condenser vacuum	Vacuum	Low	b	
Condenser condensate level	–	High and low	b	
Condensate pump	–	Stop/failure	–	
Condensate salinity	–	High	–	
Steam turbine vibration	–	Excessive	b	
Axial displacement of turbine rotor	–	Excessive	a	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
6 Auxiliary steam turbines▲				
Lub-oil inlet temperature for turbine and gearing	–	High	–	
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Condenser vacuum	–	Low	a	
Axial displacement of turbine rotor	–	Excessive	a	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
7 Main steam boilers				
Steam drum or superheater outlet pressure	Pressure	High and low	–	
Superheated steam outlet temperature	Temperature	High	–	
De-superheated steam outlet temperature	Temperature	High	–	
Boiler feed water level	Level	High	–	At least 3 sensors fitted. See 3.3.1.2(1)② and 3.3.1.3(1)② of this PART
		Low	c	
		Excessively low	a	
Temperature or viscosity of oil fuel to burners	Temperature or viscosity	Low and high	–	Only for heavy oil. Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	
Fuel oil pressure to burners	Pressure	Low	c	See 3.3.1.3(3) of this PART
Forced draft pressure	Pressure	Loss	a	2 sensors fitted
Burner flame and ignition	–	Extinguished/ ignition failure	a	Each burner is to be monitored
Fuel oil atomizing steam (air) pressure	Pressure	Low	–	
Feed pump discharge pressure or flow	Pressure or flow	Low	c	See 3.3.1.3(4) of this PART
Feed water forced circulation flow	Flow	Low	a	Required for forced circulating boilers only
Level of feed water tank	–	Low	–	Required for daily feed water tanks only

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Feed water salinity	–	High	–	
Water level of deaerator	–	High and low	–	
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
8 Auxiliary steam boilers▲				
Steam drum or superheater outlet pressure	Pressure	Low	–	
Boiler feed water level	–	High	–	See 3.3.1.2(1)② and 3.3.1.3(1)② of this PART
		Low	c	
		Excessively low	a	
Temperature or viscosity of oil fuel to burners	–	Low and high	–	Only for heavy oil. Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	
Fuel oil pressure to burners	Pressure	Low	c	See 3.3.1.3(3) of this PART
Forced draft pressure	–	Loss	a	
Burner flame and ignition	–	Extinguished/ ignition failure	a	
Feed water salinity	–	High	–	Only applicable to auxiliary steam boiler for driving turbine-generator set
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
9 Controllable pitch propeller				
Pitch or blade angle of controllable pitch propeller	Pitch or blade angle	–	–	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	–	–	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	
Hydraulic oil tank level	–	Low	–	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	
10 Vibration damper				
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	See 3.2.2.5 of this PART and 12.1.4.3 of Pt.3
11 Gearbox (for main propulsion machinery)				
Lub-oil inlet pressure of gearbox	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature of gearbox	Temperature	High	–	

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Gear oil pressure	Pressure	Low	–	
12 Clutches				
Clutch position	Position	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	See 2.8.1.11 of this PART
13 Stern tube bearing				
Oil lubricated stern tube bearing temp.	–	High	–	
Level of stern tube lubricating oil tank	–	Low	–	
14 Air compressors▲				
Air compressor lubricating oil pressure	–	Low	a	Except for splash lubrication
15 Thermal oil heaters▲				
(1) Oil-fired				
Thermal oil expansion tank level	–	Low	a	
Thermal oil flow or pressure	–	Low	a	
Thermal oil outlet temperature	–	High	a	
Combustion air pressure or forced ventilation	–	Low or shutoff	a	
Fuel oil pressure	–	Excessively low	c	
Fuel oil temperature or viscosity	–	Low or great	–	Only for heavy oil
Uptake temperature	–	High	a	
Burner flame and ignition	–	Extinguished/ ignition failure	a	Each burner is to be monitored
(2) Exhaust-fired				
Thermal oil expansion tank level	–	Low	a	
Thermal oil flow or pressure	–	Low	a	
Thermal oil outlet temperature	–	High	a	
Exhaust temperature	–	High	–	
16 Oil purifier▲				
Purifier oil outlet pressure	Pressure	Low	–	
Purifier oil inlet temperature	–	High	–	
17 Sludge tank				
Level of sludge tank	–	High	–	
18 Bilge				
Bilge level	–	High	–	See 3.9.2.1 of this PART
Bilge pumps	Indication for operation time	Too long or more frequently	–	For automatically controlled bilge pumps only, see 3.9.2.4 of this PART
19 Diesel engines driving propulsion generators				
Fuel oil inlet pressure	Pressure	Low	–	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	
Level of fuel oil in daily service tank	–	Low	–	
Common rail fuel oil pressure	–	Low	–	
Common rail servo oil pressure	–	Low	–	
Lub-oil inlet pressure	Pressure	Low	–	
		Excessively low	a	
Lub-oil filter differential pressure	Pressure	Great	–	
Lub-oil inlet temperature	–	High	–	
Speed of turbocharger	Speed	High	–	Applicable to Class B and C

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
				turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	–	
Cylinder cooling water pressure or flow	Pressure or flow	Low	–	
Cylinder cooling water outlet temperature	Temp.	High	–	
Level of cylinder cooling water in expansion tank	–	Low	–	
Starting air pressure	Pressure	Low	–	
Control air pressure	Pressure	Low	–	
Exhaust gas temp. after each cylinder	Temp.	High	–	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
20 Gas turbines driving propulsion generators				
Fuel oil pressure or flow	Pressure or flow	Low	–	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	
Turbine main bearing temperature	Temp.	High	–	
Lub-oil filter differential pressure	–	Great	–	
Level in lub-oil circulating tank	–	Low	–	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	
Coolant temperature	Temp.	High	–	
Level in fuel oil tank for ignition and starting	–	Low	–	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	
Combustion chamber flame	–	Extinguished	a	
Exhaust gas temperature	Temp.	High	a	
Gas turbine vibration	–	Excessive	a	
Axial displacement of turbine rotor	–	Great	a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and	Electrical, pneumatic	Loss	–	Indication of voltage may be replaced by indicating lamp

Item	ISC		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
hydraulic pressure)	and Hydraulic pressure			
21 Low sulphur distillate fuels				
Temperature or viscosity of fuel oil	Temperature or viscosity	High or low	–	
Temperature of fuel oil	Temperature	Low	–	When a refrigerating system for low sulphur distillate fuels is provided
Level in cooling water expansion tank (if provided) of the fuel oil cooling system	–	Low	–	
22 Miscellaneous				
Overriding function	–	When overriding is initiated	–	
Automatic systems	–	Failure	–	Including electric power fault

Section 3 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION BRC

4.3.1 General requirements

4.3.1.1 Ships with the class notation BRC are to be provided with the remote control of the main propulsion machinery and other related installations from the BCS. The machinery spaces are to be constantly attended by watch-keepers to look after the machinery and electrical equipment as described in 3.1.1.4 of this PART.

4.3.2 Functions of the BCS

4.3.2.1 Under all sailing conditions including maneuvering, the speed and direction of thrust of main propulsion machinery as well as other installations (if fitted) are to be effectively controlled from the BCS. The design and arrangement of BCS are to comply with the requirements of Section 8, Chapter 2 of this PART.

4.3.2.2 Where necessary, the control of propulsion machinery from the BCS is to be capable of being changed over to the local control station at any time and the changeover of the control is to comply with the relevant requirements of 2.5.2 of this PART.

4.3.2.3 The automatic and remote control of main engines, clutches, controllable pitch propeller, etc. is to be, in general, in compliance with the relevant requirements of Section 2, Chapter 3 of this PART.

4.3.2.4 The Mode a protective action of main engines is to be capable of being carried out automatically, the other actions (Mode b and Mode c) may be carried out by manual operation.

4.3.2.5 The bridge control of main steam turbines is to comply with the requirements in 3.2.3.2 of this PART. If the slow-turning device is arranged to be operated manually, automatic operation will not be required.

4.3.2.6 Alarms at the BCS:

(1) For the items to be alarmed at the BCS and the mode of alarms, see column 5 of Table 4.3.4.1 of this Section. Alarms indicating the faults in the machinery and electrical equipment as well as the automated control and monitoring systems are, in general, to be relayed to the BCS in the following modes: group alarms for the protective actions of safety systems; separate alarms; group alarms for serious faults and group alarms for general faults.

(2) The audible alarms at the BCS are permitted to be silenced after acknowledgment, but the visual alarms are to be extinguished only after the rectification of faults, and furthermore, the visual signals are to be capable of being clearly distinguishable before and after acknowledgment.

4.3.2.7 If the main engine is remotely started from the bridge control station, the indicator is to be fitted on the bridge control station for the starting air pressure or voltage of starting storage batteries of main engines.

4.3.3 Functions of the LCS

4.3.3.1 The LCS is to comply with the requirements in 2.5.1.5 of this PART.

4.3.3.2 The items to be displayed and alarmed, as required in columns 2 and 3 of Table 4.3.4.1 of this Section for the propulsion machinery (such as main engines, clutches, controllable pitch propeller, etc.), are to be provided at the LCS.

4.3.4 Table of automatic control and monitoring items

4.3.4.1 The automatic control and monitoring items (if fitted) for all ships with the class notation BRC are to comply with Table 4.3.4.1.

4.3.4.2 The designations used in Table 4.3.4.1 of this Section are defined as follows:

−: not required;

*: only required for trunk piston diesel engines;

S: single alarm;

G_a: group alarm activated by Mode a protective action;

G_b: group alarm activated by Mode b protective action;

R: group alarm for serious faults;

Y: group alarm for general faults.

4.3.4.3 Where "per cylinder" appears in the column "Remark" of Table 4.3.4.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, "fitted on manifold outlet" may be used to replace "per cylinder".

Automatic Control and Monitoring Items for Ships with Class Notation BRC

Table 4.3.4.1

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
1 Main diesel engine					
1.1 Fuel oil system					
Fuel oil inlet pressure	Pressure	Low	c	*Y*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Leakage from high pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tanks	–	Low	–	*Y*	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	*Y*	
1.2 Lubricating oil system					
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	*Y*	
			b	G_b	Necessary for crosshead diesel engines
		Excessively low	a	G_a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	*Y*	Required if separate lub-oil system installed for crosshead diesel engines
			b	G_b	
		Excessively low	a	G_a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to camshaft	Temp.	High	–	*Y*	
*Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	Temp.	High	–	*Y*	
Thrust bearing pad temperature or bearing temperature	Temp.	High	b	G_b	Necessary for crosshead diesel engines
		Excessively high	a	G_a	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	*Gb*	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	*Ga*	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	b	*Gb*	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	*Y*	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	*Y*	
1.3 Turbocharger system					
Turbocharger lub-oil inlet pressure	Pressure	Low	–	*Y*	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp.	High	–	*Y*	Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)					
Piston coolant inlet pressure	Pressure	Low	c	*Y*	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	*Gb*	
Piston coolant outlet flow	–	Low	b	*Gb*	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	*Gb*	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	*Y*	
1.5 Seawater cooling system					
Pressure of cooling seawater	Pressure	Low	c	*Y*	
1.6 Cylinder fresh cooling water system					

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	*Y*	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	G_b	
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temp.	High	b	G_b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
1.7 Starting and control air systems					
Starting air pressure before main shut-off valve	Pressure	Low	–	*Y*	
Control air pressure	Pressure	Low	–	*Y*	
Safety air pressure	Pressure	Low	–	*Y*	Necessary for crosshead diesel engines
1.8 Scavenge air system					
Scavenge air receiver pressure	Pressure	–	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temp.	High	b	G_b	
Scavenge air receiver water level	–	High	–	*Y*	
*Scavenge air receiver temperature	Temp.	High	–	*Y*	
1.9 Exhaust gas system					
Exhaust gas temp. after each cylinder	Temp.	High	b	G_b	For trunk piston diesel engines having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	*Y*	
Exhaust gas temperature before each turbocharger	Temp.	High	–	*Y*	Necessary for crosshead diesel engines
Exhaust gas temperature after each turbocharger	Temp.	High	–	*Y*	
1.10 Fuel valve coolant					
Pressure of fuel valve coolant	Pressure	Low	c	*Y*	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temp.	High	–	*Y*	
Level of fuel valve coolant in expansion tank	–	Low	–	*Y*	
1.11 Engine speed/direction of rotation					
Speed	Speed	Overspeed	a	G_a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	*Y*	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
2 Main gas turbines					
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	c	*Y*	
Oil level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Turbine main bearing temperature	Temp.	High	–	*Y*	
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	*Y*	
Level in fuel oil daily service tank	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temp.	High	–	*Y*	
		Excessively high	a	G_a	
Deviation of exhaust gas temperature from average	–	High	–	*Y*	
Gas turbine combustion chamber flame and ignition	–	Failure	a	G_a	
Gas turbine vibration	–	High	–	*Y*	
		Excessively high	a	G_a	
Axial displacement of turbine rotor	–	Great	–	*R*	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
3 Main steam turbines					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature for turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level of lub-oil tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temp.	High	–	*Y*	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	*Y*	
Astern turbine exhaust steam temperature	Temp.	High	–	*Y*	
Gland steam pressure	Pressure	High and low	–	*Y*	
Circulating seawater pressure or flow	Pressure or flow	Low	c	*Y*	
Condenser vacuum	Vacuum	Low	b	G_b	
Condenser condensate level	–	High and low	b	G_b	
Condensate pump	–	Stop/ failure	–	*Y*	
Condensate salinity	–	High	–	*Y*	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Steam turbine vibration	–	Excessive	b	G_b	
Axial displacement of turbine rotor	–	Excessive	a	G_a	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
4 Controllable pitch propeller					
Blade angle (or pitch) of controllable pitch propeller	Blade angle or pitch	–	–	–	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	–	–	–	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	*Y*	
Hydraulic oil tank level	–	Low	–	*Y*	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	*Y*	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	*Y*	
5 Vibration damper					
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	*Y*	See 3.2.2.5 of this PART and 12.1.4.3 of Pt.3
6 Gearbox (for main propulsion machinery)					
Lub-oil inlet pressure of gearbox	Pressure	Low	c	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature of gearbox	Temp.	High	–	*Y*	
Gear oil pressure	Pressure	Low	–	*Y*	
7 Clutches					
Clutch position	Position	–	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	See 2.8.1.11 of this PART
8 Stern tube bearing					
Oil lubricated stern tube bearing temp.	–	High	–	*Y*	
Level of stern tube lubricating oil tank	–	Low	–	*Y*	
9 Diesel engines driving propulsion generators					
Fuel oil inlet pressure	Pressure	Low	–	*Y*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tank	–	Low	–	*Y*	
Common rail fuel oil pressure	–	Low	–		
Common rail servo oil pressure	–	Low	–		
Lub-oil inlet pressure	Pressure	Low	–	*Y*	
		Excessively low	a	G_a	
Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	–	High	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	G_a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	*Y*	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	–	*Y*	
Cylinder cooling water pressure or flow	Pressure or flow	Low	–	*Y*	
Cylinder cooling water outlet temperature	Temp.	High	–	*Y*	
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
Starting air pressure	Pressure	Low	–	*Y*	
Control air pressure	Pressure	Low	–	*Y*	
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	G_a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
10 Gas turbines driving propulsion generators					
Fuel oil pressure or flow	Pressure or flow	Low	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Turbine main bearing temperature	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Level in fuel oil tank for ignition and starting	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	G_a	
Combustion chamber flame	–	Extinguished	a	G_a	
Exhaust gas temperature	Temp.	High	a	G_a	
Gas turbine vibration	–	Excessive	a	G_a	
Axial displacement of turbine rotor	–	Great	a	G_a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic	Electrical, pneumatic and	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
pressure)	hydraulic pressure				
11 Miscellaneous					
Overriding function	–	When overriding is initiated	–	*S*	
Automatic systems	–	Failure	–	*Y*	Including electric power fault

4.3.5 Requirements for automation of small ships with class notation BRC

4.3.5.1 For small ships of less than 500 gross tonnage with the class notation BRC, only group alarms activated by Mode a and Mode b protective actions as defined in Table 4.3.4.1 of this Section are to be provided in the BRC.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART EIGHT ADDITIONAL REQUIREMENTS

Table of Contents

CHAPTER 1 ADDITIONAL REQUIREMENTS FOR FIRE-FIGHTING SHIPS **1**
Section 1 GENERAL PROVISIONS 1
Section 2 BASIC REQUIREMENTS 2
Section 3 PROTECTION AND FIRE-FIGHTING EQUIPMENT 3
CHAPTER 2 ADDITIONAL REQUIREMENTS FOR LIVESTOCK CARRIERS **6**
Section 1 GENERAL PROVISIONS 6
Section 2 HULL STRUCTURE AND ARRANGEMENT 6
Section 3 STABILITY 9
Section 4 PROVISION OF LIVESTOCK SERVICES 11
Section 5 FIRE-FIGHTING APPLIANCES 12
Section 6 ELECTRICAL EQUIPMENT 13
CHAPTER 3 ADDITIONAL REQUIREMENTS FOR OIL RECOVERY SHIPS **15**
Section 1 GENERAL PROVISIONS 15
Section 2 CONSTRUCTION AND FIRE SAFETY 16
Section 3 MACHINERY INSTALLATIONS 19
Section 4 ELECTRICAL INSTALLATIONS 20
Section 5 OPERATING MANUAL 21
Section 6 OIL RECOVERY SHIPS CARRYING RECOVERED OIL HAVING A FLASH POINT EXCEEDING 60℃ 22
CHAPTER 4 SHIP BRIDGE DESIGN AND EQUIPMENT **24**
Section 1 GENERAL PROVISIONS 24
Section 2 BRIDGE LAYOUT 25
Section 3 WORKING ENVIRONMENT 28
Section 4 WORKSTATIONS 29
Section 5 EQUIPMENT AND SYSTEMS 30
Section 6 SUPPLEMENTARY REQUIREMENTS FOR THE NOTATION BDE-2 32
Section 7 INTEGRATED BRIDGE SYSTEM (IBS) 33
CHAPTER 5 ADDITIONAL REQUIREMENTS FOR FISHING VESSELS **35**
Section 1 GENERAL PROVISIONS 35
Section 2 SURVEYS DURING CONSTRUCTION 36
Section 3 SURVEYS AFTER CONSTRUCTION 37
Section 4 INTACT STABILITY 37
Section 5 DAMAGE STABILITY 38
Section 6 LOAD LINE MARKS AND MARKING 39
Section 7 STRUCTURAL ARRANGEMENT 39
Section 8 FIRE SAFETY 43
CHAPTER 6 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS **51**
Section 1 OPEN-TOP CONTAINER SHIPS ENGAGED IN UNRESTRICTED SERVICE 51
CHAPTER 7 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS **56**
Section 1 GENERAL PROVISIONS 56
CHAPTER 8 ADDITIONAL REQUIREMENTS FOR PUBLIC AFFAIR SHIPS **57**
Section 1 GENERAL PROVISIONS 57
CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY 58
Section 1 GENERAL PROVISIONS 58
Section 2 ENGINE OUTPUT 58
Section 3 HULL STRUCTURE 59
CHAPTER 10 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS **61**
Section 1 GENERAL PROVISIONS 61
Section 2 CONSTRUCTION AND ARRANGEMENT OF SHIP 62
Appendix 1 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF ASPHALT CARRIERS FITTED WITH INDEPENDENT CARGO TANKS 71

CHAPTER 11 DYNAMIC POSITIONING SYSTEMS 75
Section 1 GENERAL PROVISIONS 75
Section 2 SYSTEM ARRANGEMENT 78
Section 3 THRUSTER SYSTEM 81
Section 4 POWER SYSTEM 82
Section 5 CONTROL SYSTEM AND MEASURING SYSTEM 84
CHAPTER 12 IN-WATER SURVEY ARRANGEMENTS OF SHIPS 88
Section 1 GENERAL PROVISIONS 88
Section 2 DOCUMENTATION TO BE SUBMITTED 88
Section 3 STRUCTURAL DESIGN PRINCIPLES 88
CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS 90
Section 1 GENERAL REQUIREMENTS FOR POLAR CLASS SHIPS 90
Section 2 STRUCTURAL REQUIREMENTS 91
Section 3 MACHINERY INSTALLATIONS 106
CHAPTER 14 REDUNDANT PROPULSION SYSTEMS 136
Section 1 GENERAL PROVISIONS 136
Section 2 SYSTEM ARRANGEMENT AND DESIGN 138
CHAPTER 15 ADDITIONAL REQUIREMENTS FOR ELECTRICALLY PROPELLED SHIPS 140
Section 1 GENERAL PROVISIONS 140
Section 2 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION INSTALLATIONS 140
Section 3 STRUCTURAL REQUIREMENTS FOR PODDED 147
PROPULSION UNITS 147
CHAPTER 16 MEASUREMENT OF VIBRATION 149
AND NOISE 149
Section 1 GENERAL PROVISIONS 149
Section 2 NOISE 149
Section 3 VIBRATION 149
Section 4 MEASUREMENTS AND REPORTS 149
CHAPTER 17 ADDITIONAL REQUIREMENTS FOR GEOTEXTILES LAYERS 151
Section 1 GENERAL PROVISIONS 151
Section 2 HULL STRUCTURE AND ARRANGEMENT 151
Section 3 EQUIPMENT 152
CHAPTER 18 ADDITIONAL REQUIREMENTS FOR HEAVY EQUIPMENT CARRIER 153
Section 1 GENERAL PROVISIONS 153
Section 2 OUTFITTINGS 153
Section 3 INTACT STABILITY 153
Section 4 SPECIAL REQUIREMENTS FOR EXTRA BALLAST OPERATION 153
Section 5 EXTRA BALLAST OPERATIONAL PROCEDURE MANUAL 155
CHAPTER 19 AC SHORE CONNECTION SYSTEMS 157
Section 1 GENERAL PROVISIONS 157
Section 2 SYSTEM DESIGN 159
Section 3 ELECTRICAL EQUIPMENT 160
Section 4 SURVEY AND TESTING 162
CHAPTER 20 ADDITIONAL REQUIREMENTS FOR ANCHOR HANDLING 163
Section 1 GENERAL PROVISIONS 163
Section 2 HULL STRUCTURE 163
Section 3 ANCHOR HANDLING EQUIPMENT AND SUPPORTING STRUCTURES 163
CHAPTER 21 HULL MONITORING SYSTEMS 165
Section 1 GENERAL PROVISIONS 165
Section 2 SYSTEM DESIGN 166
Section 3 DATA PROCESSING AND STORAGE 167
Section 4 DISPLAY AND MONITORING 170
Section 5 COMPONENT REQUIREMENTS 171
CHAPTER 22 ADDITIONAL REQUIREMENTS FOR ERGONOMIC CONTAINER LASHING 173
Section 1 GENERAL PROVISIONS 173
Section 2 SAFE ACCESS DESIGN 173
Section 3 LASHING SYSTEMS 178
Section 4 LIGHTING DESIGN 179
Section 5 SPECIALIZED CONTAINER SAFETY DESIGN 179

CHAPTER 23 ADDITIONAL REQUIREMENTS FOR SHIPS OPERATING IN LOW AIR TEMPERATURE ENVIRONMENTS 180
Section 1 GENERAL PROVISIONS 180
Section 2 MATERIALS AND WELDING 182
Section 3 SHIP ARRANGEMENTS 186
Section 4 STABILITY 187
Section 5 WATERTIGHT AND WEATHERTIGHT INTEGRITY 188
Section 6 MACHINERY INSTALLATIONS 188
Section 7 FIRE FIGHTING 193
Section 8 LIFE-SAVING APPLIANCES AND ARRANGEMENTS 194
Section 9 NAVIGATIONAL SAFETY 195
Section 10 SHIP TYPE SPECIFIC ADDITIONAL REQUIREMENTS 195
Section 11 ANTI-ICING AND DE-ICING MEASURES 199
Section 12 SURVEY REQUIREMENTS FOR ANTI-COLD CLIMATE NOTATIONS 203
CHAPTER 24 ADDITIONAL REQUIREMENTS FOR STAND-BY SHIPS AND RESCUE SHIPS 206
Section 1 GENERAL PROVISIONS 206
Section 2 CONSTRUCTION AND ARRANGEMENT 206
Section 3 ACCOMMODATION SPACES FOR SURVIVORS 207
Section 4 RESCUE AND SAFETY EQUIPMENT 207
Section 5 NAVIGATION AND COMMUNICATION EQUIPMENT 209
CHAPTER 25 ADDITIONAL REQUIREMENTS FOR DIVING SUPPORT VESSELS 210
Section 1 GENERAL PROVISIONS 210
Section 2 SEA KEEPING OF VESSEL'S POSITION 211
Section 3 ARRANGEMENT OF DIVING SYSTEMS 211
Section 4 STRUCTURAL REQUIREMENTS 213
Section 5 FIRE-FIGHTING 213
Section 6 UNMANNED REMOTELY OPERATED VEHICLE SUPPORT 215
Section 7 SURVEY, INSPECTION AND TESTING 215
CHAPTER 26 ADDITIONAL REQUIREMENTS FOR INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS 216
Section 1 GENERAL PROVISIONS 216
Section 2 INSTALLATION 219
Appendix 1 ADDITIONAL FIRE SAFETY MEASURES RELATED TO THE INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS 227
Appendix 2 INSTALLATION OF ONE SINGLE BWMS ON TANKERS 233
CHAPTER 27 BOW LOADING SYSTEMS 253
Section 1 GENERAL PROVISIONS 253
Section 2 ARRANGEMENT 253
Section 3 EQUIPMENT AND OUTFITS 254
Section 4 PIPING SYSTEMS 254
Section 5 CONTROL AND MONITORING 255
Section 6 FIRE SAFETY 256
Section 7 OPERATION MANUAL 257
Section 8 TESTING AND SURVEY 257
Section 9 REQUIREMENTS FOR BOW LOADING SYSTEM* 258
CHAPTER 28 ADDITIONAL REQUIREMENTS FOR CABLE LAYERS 259
Section 1 GENERAL PROVISIONS 259
Section 2 HULL STRUCTURE AND ARRANGEMENT 259
CHAPTER 29 ADDITIONAL REQUIREMENTS FOR PIPE LAYERS 261
Section 1 GENERAL PROVISIONS 261
Section 2 HULL STRUCTURE AND ARRANGEMENT 261
Section 3 EQUIPMENT 261
CHAPTER 30 ADDITIONAL PROVISIONS ON THE FUNCTIONALITY OF RO-RO PASSENGER SHIPS 262
Section 1 GENERAL PROVISIONS 262
Section 2 PASSENGER AND VEHICLE EMBARKATION AND DISEMBARKATION ARRANGEMENT 262
CHAPTER 31 NOTATIONS FOR OTHER EQUIPMENT 263
Section 1 GENERAL PROVISIONS 263
Section 2 NOTATION FOR VIDEO MONITORING SYSTEM 263

Section 3 NOTATION FOR NIGHT VISION EQUIPMENT 264
Section 4 NOTATION FOR FOG NAVIGATION ENHANCED SENSING 264
CHAPTER 32 TRANSVERSE PROPULSION ARRANGEMENT 267
Section 1 GENERAL PROVISIONS 267
Section 2 TRANSVERSE PROPULSION ARRANGEMENT 267
Section 3 CONTROL, MONITORING AND ALARM 268
CHAPTER 33 SHIP COMMUNICATION NETWORKS SATISFYING SPECIFIC NEEDS 269
Section 1 GENERAL PROVISIONS 269
Section 2 TECHNICAL REQUIREMENTS 269
Section 3 PLANS AND DOCUMENTS 270
Section 4 SURVEY AND TESTS 271
CHAPTER 34 EVALUATION OF COLLISION RESISTANCE CAPABILITY OF SHIPS 272
Section 1 GENERAL PROVISIONS 272
Section 2 EVALUATION METHODS 273
Section 3 EVALUATION CRITERIA 273
Section 4 CRITICAL STRIKING SPEED CURVE 273
CHAPTER 35 SYSTEM AND EQUIPMENT READY 274
Section 1 GENERAL PROVISIONS 274
Section 2 READY CLASS NOTATIONS 274
Section 3 TECHNICAL REQUIREMENTS AND PLANS AND INFORMATION 274
CHAPTER 36 ONBOARD CARBON CAPTURE SYSTEM 275
Section 1 GENERAL PROVISIONS 275
Section 2 DESIGN AND ARRANGEMENT 275
Section 3 SURVEYS 276
CHAPTER 37 ADDITIONAL REQUIREMENTS FOR CARRYING DRY CARGO IN BULK 277
Section 1 GENERAL PROVISIONS 277

CHAPTER 1 ADDITIONAL REQUIREMENTS FOR FIRE-FIGHTING SHIPS

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 This Chapter applies to the fire-fighting ships applying for one of the class notations listed in 1.1.2 below.

1.1.1.2 The fire-fighting ships intended to extinguish the following fires respectively are divided into Grades 1, 2 and 3 in this Chapter:

Fire-fighting ships of Grade 1 are for early stage fire-fighting;

Fire-fighting ships of Grade 2 are for large fire-fighting;

Fire-fighting ships of Grade 3 are for large or oil fire-fighting.

1.1.1.3 The fire-fighting ships are to comply with the requirements of this Chapter and in addition, the applicable requirements in other PARTs of the Rules and the requirements of ISC Rules for Materials and Welding.

1.1.1.4 The minimum requirements for fire-fighting ships of Grades 1, 2 and 3 are listed in Table 1.1.1.4.

List of Minimum Requirements for Fire-Fighting Ships Table 1.1.1.4

Equipment	Grade of fight-fighting ships			
	1	2		3
Minimum number of water monitors	2	3	4	4
Minimum discharge rate per monitor, in m^3/h	1200	2400	1800	2400
Minimum number of fire pumps	1	2		2
Minimum total pump capacity, in m^3/h	2400	7200		9600
Performance of water monitors: Minimum height of trajectory of jets of monitors above sea level, in m Minimum range of monitors jets, in m	 45 120	 70 150		 70 150
Minimum fuel capacity for simultaneous working of all water monitors, in h	24	96		96
Fixed foam fire-extinguishing system: Minimum number of foam monitors Minimum discharge rate per system, in m^3/h Time of continuous foam production, in min	 – – –	 – – –		 2 300 30
Mobile fire-fighting equipment: Portable foam generator Minimum foam capacity, in m^3/min Time of continuous foam production, in min	 – –	 100 30		 100 30
Fire hoses Number of hose connections each side of ship	 4	 8		 8
Number of fireman's outfits	4	8		8

1.1.1.5 Where it is necessary for fire-fighting ships to deviate from the requirements of this Chapter due to their specific missions such as geographical limitations or particular objects to be served, ISC may impose other requirements as appropriate on such ships. And individual requirements in this Chapter may also be relaxed subject to agreement of ISC.

1.1.2 Notations

1.1.2.1 For all grades of fire-fighting ships complying with the requirements in this Chapter, the following notations are to be granted respectively:

Fire-fighting ships of Grade 1: Fire-Fighting Ship 1;

Fire-fighting ships of Grade 2: Fire-Fighting Ship 2;

Fire-fighting ships of Grade 3: Fire-Fighting Ship 3.

1.1.2.2 For ships provided with a water spraying system complying with 1.3.1 of this Chapter for delivering efficient cooling water spraying over all the exposed vertical surfaces of the hull so as to enable the ship to approach the burning object for fire-fighting and/or rescue purposes, the notation of Water Spraying may be affixed to that mentioned in 1.1.2.1 of this Section.

1.1.3 Plans and documents to be submitted

1.1.3.1 In addition to those required in the relevant Chapters of the Rules, the following plans and documents are to be submitted for approval:

(1) Arrangement and specification of water monitor system (including capacity, range and jet trajectory of pumps and monitors);

(2) Plan of seating arrangements for water monitors;

(3) Arrangement of water spray systems (if provided);

(4) Arrangement and specification of fireman's outfits and air compressors;

(5) Arrangement and specification of searchlights;

(6) Plan of remote control system of monitors;

(7) Arrangement of hose connection positions and associated piping on each side of ship;

(8) Stability calculations for fire-fighting operations;

(9) Operation manual, including:

① detailed description of each fire-fighting system and equipment;

② instructions on use, test and maintenance of fire-fighting installations and equipment;

③ instructions on maneuvering of ship during fire-fighting.

1.1.3.2 In addition to the plans and documents required in the relevant Chapters of the Rules, the following documents are to be submitted for information:

(1) Particulars of the means of keeping the ship in position during fire-fighting operations;

(2) Estimation of fuel consumption during fire-fighting operations.

1.1.3.3 For fire-fighting ships of Grade 2 or Grade 3, in addition to the plans and documents required in 1.1.3.1 and 1.1.3.2, the following plans and documents are to be submitted for approval:

(1) For fire-fighting ships of Grade 2:

Arrangement and specification of mobile fire-fighting equipment;

(2) For fire-fighting ships of Grade 3:

① Arrangement and specification of mobile fire-fighting equipment;

② Plan of seating arrangements for foam monitors;

③ Arrangement and specification of foam systems;

④ Plan of remote control system of foam monitors.

1.1.3.4 Other plans and documents are to be additionally submitted for approval or for information where deemed necessary.

Section 2 BASIC REQUIREMENTS

1.2.1 Hull structure

1.2.1.1 The hull structure is to be strengthened if necessary to withstand the forces imposed by the fire-fighting systems when operating at their maximum capacity.

1.2.2 Stability

1.2.2.1 When all monitors are in operation at full capacity in the most adverse direction for the stability, the ship is to have satisfactory stability corresponding to the load conditions.

1.2.3 Maneuverability

1.2.3.1 The ships are to have side thrusters and propulsion machinery with sufficient power for adequate maneuverability during fire-fighting operations. However, if means are provided to keep the ship at a standstill during fire-fighting operations, side thrusters may not be provided.

1.2.3.2 Side thrusters (if any) and main propellers are to keep the ship at a standstill in calm waters at all combinations of capacity and direction of throw of the water monitors and foam monitors, and the most unfavourable combination is not to be more than 80% of the available propulsion force in any direction.

1.2.3.3 In order to prevent overloading during combined manoeuvring, means are to be provided for sending visual and audible alarms to the navigating bridge at 80% of the available propulsion power, and for automatically reducing the power at 100% of the available propulsion force, so as to prevent sudden or complete loss of power due to power overload.

1.2.3.4 A simple control system is to be provided for operating the main propulsion plant and side thrusters (if any) to adjust:

(1) the resultant thrust vector for the ship;

(2) the turning moment of the ship;

(3) the ship's heading.

1.2.4 Lighting

1.2.4.1 Two searchlights are to be provided to permit operations of the fire-fighting equipment at night.

1.2.4.2 The searchlights are to be capable of providing at a range of 250 m in clear atmospheric conditions a level of illumination of 50 lx within an area of not less than 11 m diameter. They are to be capable of being adjusted in the horizontal and vertical directions.

1.2.5 Fuel capacity and replenishment

1.2.5.1 The quantity of fuel oil for continuous fire-fighting operations at maximum required capacity is at least to comply with Table 1.1.1.4 of this Chapter.

1.2.5.2 The fuel capacity is to be additional to what is provided for normal operation of the ship, e.g. ship's propulsion.

1.2.5.3 Where necessary, consideration is to be given to the requirement that any fuel which may be required while the ship is operating on station can be safely received on board.

1.2.6 Operation manual

1.2.6.1 An approved operation manual is to be kept on board.

Section 3 PROTECTION AND FIRE-FIGHTING EQUIPMENT

1.3.1 Water spray systems

1.3.1.1 Where a fire-fighting ship is provided with a fixed water spray system, the system is to ensure a protection of all outside vertical areas of hull above waterline, including superstructures, deckhouses, seatings for water monitors and other fire-fighting equipment.

1.3.1.2 The water spray system is to have a capacity of at least 5 *l*/min per m^2 of the protected area which is internally insulated to A-60 class and at least 10 *l*/min per m^2 of other protected areas.

1.3.1.3 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area exposed to radiant heat from a fire. Where the main fire pumps are used for this purpose, they are to be capable of operating this system, the water monitors and the hose stations simultaneously at the required pressure. A connection with an isolating valve is to be fitted between the piping system for the water monitors and the supply line for the water spray system.

1.3.1.4 The water spray system is to be divided into sections so that it will be possible to close down sections covering surfaces which are not exposed to radiant heat.

1.3.1.5 The nozzles of the water spray system are to be arranged to give an even distribution of water spray over the protected areas.

1.3.1.6 Deck scuppers and freeing ports are to be of sufficient area to ensure efficient drainage of water from decks and horizontal surfaces in all conditions when the water spray system is in operation.

1.3.1.7 Means are to be taken to ensure that necessary visibility from the navigation bridge and the remote-control station can be maintained during the water spray operations.

1.3.2 Water monitor systems

1.3.2.1 The minimum number of water monitors and their characteristics are to comply with Table 1.1.1.4 of this Chapter.

1.3.2.2 Arrangement of water monitor systems

(1) The water monitors are to be capable of being adequately adjusted in the vertical and horizontal directions to achieve the best target point of the jet, and to be so positioned that the jets will be unimpeded within the required range of operation.

(2) The water monitors are to be fitted on fixed and robust seatings so as to withstand the imposed forces from all modes of operation.

(3) At least two water monitors are to be equipped with a permanently fitted nozzle which can give solid or a spray jet as required.

1.3.2.3 Control of water monitors

In addition to the local manual operation, the monitors are to be capable of being activated and maneuvered by remote control from a protected position ensuring a good view of the monitors and of the area to be served.

1.3.2.4 Design and seating arrangements of water monitors

(1) The monitors are to be of robust construction to withstand shock loading when all the monitors are activated simultaneously.
(2) The seating arrangements of the monitors are to be of adequate strength for all modes of operation.
1.3.2.5 Pumps and piping systems
The pumps and piping systems are to comply with the relevant requirements of 1.3.4 of this Section.

1.3.3 Fixed foam monitor system
1.3.3.1 For fire-fighting ships of Grade 3, in addition to a water monitor system, a fixed low-expansion foam monitor system complying with this paragraph is to be provided.
1.3.3.2 Performance and capacity
(1) Two foam monitors are to be provided on board, each with a capacity not less than 300 m^3/h and a foam expansion ratio not more than 12:1.
(2) The arrangement and positions of the monitors and foam system are to be such that a height of throw at least 50 m above the sea level can be obtained, when both monitors are used simultaneously with maximum capacity.
(3) Sufficient foam concentrate is to be available for at least 30 min. of simultaneous operation of both monitors at maximum capacity. When determining the required capacity of the foam concentrate, the concentration ratio is to be assumed 5%.
1.3.3.3 Arrangement
(1) The foam generating system is to be of a fixed type, consisting of individual foam concentrate tank, foam-mixing unit and piping to the monitors.
(2) The system may be supplied by the pumps of water monitors. In such cases, the pump pressure is to be adjustable to ensure producing the maximum capacity of foam.
1.3.3.4 Control of foam monitors
In addition to the local manual control, foam monitors are to be provided with remote control which is to include the operation of the valves necessary for the control of both water and foam. The remote control of foam monitors is to be located at the same remote-control station for water monitors.
1.3.3.5 Design and seating arrangements of foam monitors
(1) The foam monitors are to be of robust construction.
(2) The seating arrangements of the monitors are to be of adequate strength for all modes of operation.
1.3.3.6 Pumps and piping systems
The pumps and piping systems are to comply with the relevant requirements of 1.3.4 of this Section.

1.3.4 Pumps and piping systems for water and foam
1.3.4.1 General requirements
(1) The pumps and piping systems conveying water and foam are not to be used for other services, except for the water spray system referred to in 1.3.1 of this Chapter and for the fire-extinguishing system of the ship itself.
(2) Where the pumps are used for the fixed water spray systems, the piping is to be independent from that serving the monitors.
(3) The piping system from the pumps to the water monitors is to be separate from the piping system to the hose connections required for the mobile fire-fighting equipment as specified in 1.3.5 of this Chapter.
(4) The piping systems are to have arrangements to avoid overheating of the pumps at low delivery rates.
(5) Suction lines are to be as short and straight as practicable. The design maximum water velocity in the suction lines is normally not to exceed 2 m/s.
(6) Piping between pumps and water monitors is to have a maximum design water velocity normally not exceeding 4 m/s.
(7) All piping from seawater inlets to water monitors is to be internally protected against corrosion. Piping exposed to the weather is to be protected also externally.
1.3.4.2 Arrangement of pumps
The pumps for fire-fighting systems and their prime movers are to be adequately protected, and so located that they will be easily accessible during operation and maintenance.
1.3.4.3 Seawater suctions
(1) Seawater suctions for the fire-fighting pumps are not to be used for other purposes.
(2) The seawater suction valve, pressure valve and the pump motor are to be operable from the same position. Valves with nominal diameter exceeding 450 mm are to be power actuated as well as manually operable.
(3) Starting of fire-fighting pumps when water inlet valves are closed is to be prevented either by an interlock system or by an audible and visual alarm.

(4) Seawater inlets and sea chests are to be of a design ensuring an even and sufficient supply of water to the pumps. The location of the seawater inlets and sea chests is to be such that the water supply is not impeded by the ship's motions or by the water flow to and from bow thrusters, side thrusters, azimuth thrusters or main propellers.
(5) Seawater suctions of the fire-fighting pumps are to be arranged as low as practicable to avoid icing.
(6) Seawater suctions are to be fitted with gratings having a free passage area not less than twice that of the sea suction valve, and efficient means are to be provided for cleaning the gratings in order to ensure the efficient operation of pumps.

1.3.5 Mobile fire-fighting equipment

1.3.5.1 For fire-fighting ships of Grade 2 or 3, the mobile fire-fighting equipment complying with 1.3.5.2 of this Section is to be provided.
1.3.5.2 High-expansion foam generator
(1) Where required in Table 1.1.1.4 of this Chapter, the mobile high-expansion foam generator is to be provided with a capacity not less than 100 m^3/min for fighting external fires.
(2) Foam-forming liquid is to be stored in portable containers of about 20 *l* individual capacities. The total capacity of foam-forming liquid is to be sufficient for 30 min of continuous foam production.

1.3.6 Fire Hoses

1.3.6.1 Hose stations are to be provided on each side of the ship in accordance with the number required in Table 1.1.1.4 of this Chapter.
1.3.6.2 Each hose station is to be provided with a hydrant, a hose and a nozzle capable of producing a jet or a spray and simultaneously a jet and a spray.
1.3.6.3 The hoses are in general to be 15 m in length and not less than 38 mm nor more than 65 mm in diameter.

1.3.7 Fireman's outfit

1.3.7.1 Fire-fighting ships are to be provided with fireman's outfit in accordance with Table 1.1.1.4 of this Chapter.
1.3.7.2 Each self-contained breathing apparatus is to have a capacity of at least 1,200 *l* of free air, and at least one spare air bottle is to be provided for each apparatus.
1.3.7.3 The fireman's outfit is to be stored in a safe position readily accessible from the open deck.
1.3.7.4 A suitable air compressor is to be provided for recharging the air cylinders. It is to be capable of recharging the cylinders used in the breathing apparatus of all the fireman's outfits required in Table 1.1.1.4 of this Chapter (excluding the spare air cylinders) within 30 min. The air quality in the recharged cylinders is to be suitable for human respiration.

CHAPTER 2 ADDITIONAL REQUIREMENTS FOR LIVESTOCK CARRIERS

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies to livestock carriers.

2.1.1.2 Livestock carriers complying with the requirements of this Chapter are eligible for the assignment of the notation: Livestock Carrier.

2.1.1.3 In addition to the provisions of this Chapter, livestock carriers are to comply with the applicable requirements for livestock carriers in other chapters of the Rules, ISC Rules for Materials and Welding and relevant requirements of the flag State Administration (if any).

2.1.2 Definitions

2.1.2.1 Livestock carrier refers to a sea-going steel ship constructed or adapted and used solely for the carriage of livestock cargoes. Livestock includes sheep, cattle, horses and pigs, etc.

2.1.2.2 Secondary power source refers to the source of power which may supply independent power for livestock service systems if the main source of power is out of action.

2.1.3 Plans and documents

2.1.3.1 In addition to the plans and documents as specified in relevant chapters of the Rules, the following plans and documents are to be submitted for approval:

(1) Arrangement of livestock pens and passageways;

(2) Constructions of livestock pens and passageways;

(3) Diagram of storage and distribution systems for fodder and water;

(4) Diagram of the water washing system;

(5) Diagram of the sewage drainage and discharge system;

(6) Arrangement of fire-fighting appliances in livestock spaces;

(7) Diagram of secondary power source system;

(8) Arrangement of secondary power sources spaces;

(9) Piping diagram related to secondary power sources.

2.1.3.2 The following plans and documents are to be submitted for information:

(1) Diagram of the ventilation system, with indication of the gross volume and calculations of air change rates of the enclosed spaces;

(2) Specifications of fire-fighting appliances;

(3) Estimation of fuel consumption of secondary source of power and estimation of time for restarting (restoration) of secondary source of power (if applicable).

Section 2 HULL STRUCTURE AND ARRANGEMENT

2.2.1 Hull structure

2.2.1.1 The structure of livestock carriers is to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

2.2.1.2 Where superstructure deck is strength deck (contributing to the longitudinal strength), the thickness of deck plating, excluding that of the forecastle, is to comply with the requirements of 2.17.5.4 in Chapter 2 of PART TWO and the buckling strength requirements in respect to longitudinal strength of Section 2, Chapter 2 of PART TWO, but not less than 6 mm.

2.2.1.3 Where superstructure deck is strength deck (contributing to the longitudinal strength), the framing of superstructure deck is to comply with the relevant requirements of Section 8, Chapter 2 of PART TWO and the buckling strength requirements in respect to longitudinal strength of Section 2, Chapter 2 of PART TWO.

2.2.2 Livestock arrangement and protection of livestock

2.2.2.1 The livestock is to be kept in pens. The dimensions of these pens are to be suitable for the livestock carried and are to comply with the requirements in Table 2.2.3.5.

2.2.2.2 Arrangements for protecting the livestock from injury, avoidable suffering and exposure to weather, sea or heat source are to be provided.
2.2.2.3 Livestock may not be carried or loaded for carriage on or in any part of a ship where the livestock, livestock fittings, livestock equipment or arrangements may:
(1) obstruct access to any accommodation space or working space necessary for the safe running of the ship, or the means of egress from any hold or underdeck space;
(2) interfere with life-saving or fire-fighting appliances;
(3) interfere with the tank sounding equipment or bilge pumping;
(4) interfere with the operation of closing appliances;
(5) interfere with the operation of freeing ports;
(6) interfere with the lighting or ventilation of other parts of the ships;
(7) interfere with the proper navigation of the ship.
2.2.2.4 If the casing or bulkhead of an engine room, boiler room or heated fuel tank forms the boundary of a space in which livestock is to be carried, appropriate heat insulation is to be provided.
2.2.2.5 The following measures are to be taken to avoid hurt to livestock from exposed steel structure during the movement of livestock:
(1) protective boards are to be fitted on both sides of upper and lower passageways;
(2) protective boards are to be fitted on pens adjacent to the bulkhead with stiffeners or similar structures.

2.2.3 Livestock pen, means of access for livestock and livestock deck

2.2.3.1 A ramp or other suitable means of access appropriate to the species, is to be provided for the loading or unloading of livestock. It is to be so erected as to prevent any gap occurring between it and the ship and is to be set at a gradient suitable for the species to be loaded or unloaded.
2.2.3.2 A means of access is to be fitted with:
(1) side panels free of protrusions and of sufficient strength and height to prevent escape of livestock;
(2) a walking surface of battens suitable for the species; and
(3) a closing arrangement.
2.2.3.3 If a means of access is part of the ship's equipment, it is to be designed to support a uniformly distributed load over the walking surface not less than the values specified in Table 2.2.3.3.

Table 2.2.3.3

Species	Load (N/m^2)
Cattle and horses	4700
Sheep, goats and pigs	2400

2.2.3.4 The permissible tensile stress for material used in the construction of a means of access is specified in Table 2.2.3.4.

Table 2.2.3.4

Material	Permissible tensile strength
Steel	$R_{eH}/2$
Aluminum	$R_{p0.2}/2$
Other	To be specially considered by ISC

2.2.3.5 Livestock pen and means of access for livestock are to comply with the requirements of Table 2.2.3.5.

Limits for pens and passageways of sheep and pigs **Table 2.2.3.5(1)**

Maximum breadth	4.5 m
Minimum breadth	2.0 m
Maximum length	Not more than twice the breadth
Minimum length	Not less than the breadth
Maximum clear floor area within pen	40.5 m^2
Minimum clear height within pen	1.1 m
Maximum clear vertical distance between rails	0.3 m
Maximum clear vertical distance below bottom edge of lowest rail of pen installed at deck level	0.2 m
Maximum clear vertical distance below bottom edge of lowest rail of pen not installed at deck level	0.05 m
Minimum height of top edge of uppermost rail above pen floor	0.9 m
Minimum width of adjacent passageway clear of receptacles and any other obstructions	0.55 m

Limits for pens and passageways of cattle **Table 2.2.3.5(2)**

Maximum breadth	4.5 m
Minimum breadth	2.1 m
Minimum length	2.3 m
Maximum clear floor area within pen	21 m^2
Maximum height of top edge of lowest rail above pen floor between pens	0.6 m
Minimum clear height within pen	1.8 m if a mechanical ventilation system is provided 2.3 m in any other case
Minimum width of adjacent passageway, measured clear between rails, when pens are on both sides of the passageway and cattle are loaded and discharged through the pens	1.0 m
Minimum width of adjacent passageway, measured clear of any fixed structure, fittings, receptacles or obstruction (eg pillars, feed chutes, fixed fodder or water troughs), when pens are on both sides of the passageway and cattle are loaded and discharged through the pens	0.7 m
Minimum width of adjacent passageway, measured clear of any fixed obstructions, when pens are on both sides of the passageway and cattle are loaded and discharged through the passageway	1.0 m
Minimum width of adjacent passageway measured clear from rails, when pens are on one side only of the passageway	0.75 m

Limits for stalls, pens and passageways of horses **Table 2.2.3.5(3)**

Maximum clear length within stall		2.5 m
Minimum clear length within stall		2.3 m
Minimum clear passage	(1) between 2 rows of stalls and bounded by the front rails	1.7 m
	(2) between 2 rows of stalls and bounded by front and back rails	1.2 m
	(3) in any other case	1.0 m
Minimum clear breadth within stall	(1) if the stall is aligned athwartships	0.7 m
	(2) if the stall is aligned fore and aft	0.9 m
Height of uppermost front, back and side rail from floor to top edge		1.15 m
Height of lowest front, back and side rail from floor to top edge		0.75 m

Note: Pens dedicated for the carriage of other livestock are to be submitted to ISC for special consideration.

2.2.3.6 Livestock pens are to be designed based on the load determined by the application of the following formula:

$$F = \alpha b\left[0.574 + 0.0252\left(Z + \gamma\right)\right] \quad \text{N/m}$$

where: α — coefficient, taken as 1668 for sheep or pigs and 3336 for cattle or horses;
b — maximum breadth of pen, in m;
Z — the vertical distance from the ship's minimum draught water-line to the pen floor;
γ — coefficient, taken as 0.5 for sheep or pigs and 0.75 for cattle or horses.

Load bearing areas are:
for sheep and pigs: uniformly distributed up to the rail the centre of which is at a height of not more than 0.9 m above the pen floor;
for cattle and horses: uniformly distributed up to the rail the centre of which is at a height of not more than 1.40 m above the pen floor.

2.2.3.7 Livestock pen floors or platforms are to be designed according to the following formula with the load uniformly distributed in any two-thirds of the area of the pen:

$$P = \beta\left[1 + ((0.094 - 0.00035L)\,y + (7.4 - 0.016L))/d\right] \text{ N/m}^2$$

where: β — coefficient, taken as 2500 for sheep or pigs and 5000 for cattle or horses;
d — minimum draught of the ship, in m;
y — longitudinal distance from the midpoint of the pen to amidships, in m;
L — length between the perpendiculars of the ship, in m.

2.2.3.8 The permissible stresses of livestock pens and floors are given in Table 2.2.3.8.

Table 2.2.3.8

Material	Permissible tensile stress	Permissible shear stress
Steel	$0.75R_{eH}$	$0.375\,R_{eH}$
Aluminium	$0.75\,R_{p0.2}$	$0.375\,R_{eH}$

Other	To be specially considered by ISC	To be specially considered by ISC

2.2.4 Means of egress and access for persons

2.2.4.1 Each space in which livestock is carried is to be provided with no fewer than two means of egress widely separated and giving access to an open deck.

2.2.4.2 Access to a livestock space for persons is to be safe and, if combined with a ramp used for moving livestock between decks, is to be separated from the livestock ramp by protective fencing.

2.2.4.3 A pen, stall or similar fitting is to be provided with a means of access for persons with a secure closing arrangement having a structural strength equivalent to the strength of that part of the pen, stall or fitting.

2.2.4.4 If access is required between a vessel's side and a pen, stall or similar fitting for the purposes of the safe and proper operation of the vessel, a passageway is to be provided that has a clear width of not less than 750 mm between the vessel's rail or bulwark and the rails or receptacles of the pen, stall or fitting, except that obstructions outside the pen rails may reduce the passageway measured from the vessel's rail to 550 mm.

2.2.4.5 Where it is necessary for persons to be on a means of access during the movement of livestock, a passage of not less than 550 mm width is to be provided, which is to be:

(1) fenced to a height of not less than 1 m and with an intermediate horizontal rail approximately 550 mm above the walking surface; and

(2) fitted with treads at suitable stepping distances.

2.2.4.6 The passageways in spaces for the carriage of livestock are to have a minimum clear height of 2.0 m.

Section 3 STABILITY

2.3.1 General requirements

2.3.1.1 The stability of livestock carriers is to comply with the requirements of this Section or relevant requirements of the flag State Administration.

2.3.1.2 The stability of livestock carriers is to comply with the requirements for cargo ships in Sections 9 and 10 of Chapter 1, PART TWO of the Rules.

2.3.2 Additional requirements for stability

2.3.2.1 The effects of the shift of livestock and fodder in pellet form (if any) and the effect of wind are to be taken into account for intact stability of livestock carriers. The following criteria are to be complied with for livestock carriers under intact condition:

(1) The angle of heel is not to exceed 10 degrees due to the effect of wind.

(2) The residual area *A* is to comply with the following requirements, taking into account the effects of the shift of livestock and fodder in pellet form and the effect of wind, as illustrated in Figure 2.3.2.1 below:

$$A \geq 0.018 \text{ m•rad} + 0.2A_{(A+B)}$$

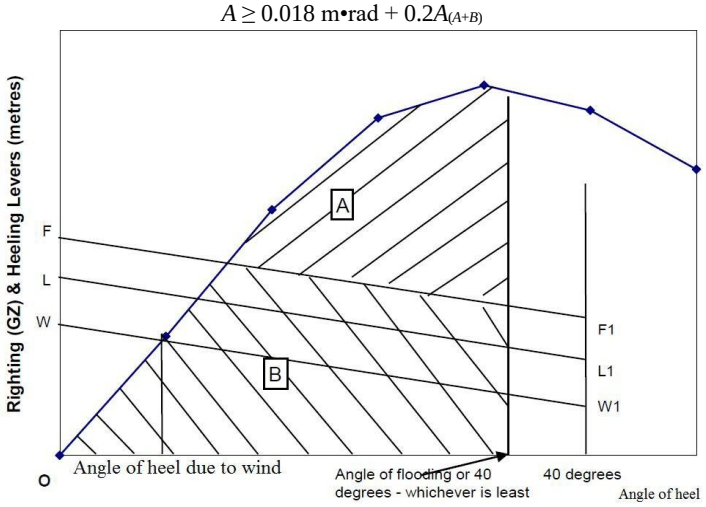


Figure 2.3.2.1 Rolling Criteria

where: $A_{(A+B)}$ is the sum of area *A* and area *B* under the righting lever curve, as illustrated in Figure 2.3.2.1. Definitions in Figure 2.3.2.1 are as follows:

OW — the heeling lever at 0° due to wind;
WW_1 — the heeling lever curve due to wind;
WL — the heeling lever at 0° due to the shift of livestock;
LL_1 — the heeling lever curve due to the combined effects of wind and the shift of livestock;
LF — the heeling lever at 0° due to the effect of shift of fodder;
FF_1 — the heeling lever curve due to the combined effects of wind and the shift of livestock and fodder;
θ — the angle of heel due to wind.

Note: If fodder is not pellet feed carried in bulk, the heeling lever due to shift of fodder will be zero.

(3) The heeling lever due to the effect of wind is to be determined according to the following requirements:

① The heeling lever due to the effect of wind at 0° is to be given by $OW = \frac{PAH}{\Delta}$,

where: Δ — displacement, in t;
P — wind pressure, 504 pa;
A — lateral area of the vessel above the waterline, in m^2;

H — vertical distance between the centroid of the lateral area of the vessel above the waterline and the centroid of the vessel's underwater lateral area. For most vessels the vertical position of the centroid of the underwater lateral area may be taken as half the draft to the underside of the keel at amidships.

② The heeling lever due to the effect of wind at 40° is to be given by 0.8 (heeling lever due to the effect of wind at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

(4) The heeling lever due to the shift of livestock is to be determined according to the following requirements:

① The heeling lever due to the shift of livestock at 0^o is to be given by $\frac{m \cdot C}{f \cdot \Delta}$,

where: m — average mass of livestock to be carried on the intended voyage, in t;
f — floor area required per head of average mass of the livestock to be carried on the intended voyage, in m^2;

C — livestock shift constant, $C = \frac{1}{6}\sum lb^2$, where l is length of each pen, in m; b is breadth of each pen, in m. For vessels with uniform breadth of pens, the livestock vessel constant becomes: 1/6 (breadth of pen × total floor area of pens). For vessels with varying breadths of pens, the largest breadth may be used and the livestock shift constant becomes: 1/6 (maximum breadth of pen × total floor area of pens).

② The heeling lever due to the shift of livestock at 40° is to be given by 0.8 (heeling lever due to the shift of livestock at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

(5) The heeling lever due to the shift of fodder is to be determined according to the following requirements:

① The heeling lever due to the shift of fodder at 0° is to be given by $\frac{M_f}{s \cdot \Delta}$,

where: M_f — the sum of the shift moment of each compartment, where the shift moment of each compartment is to be given by 0.044 lb^3, where: l is the maximum length of the compartment; and b is the maximum breadth of the compartment, in m. The use of volumetric shift moments for the fodder, where the surface is assumed to take up an angle of slope of 15° to the horizontal for full compartments and 25° to the horizontal for partly filled compartments, is an acceptable alternative method to obtain the total shift moment of fodder;

s — stowage factor (the volume of fodder in pellet form per unit weight).

② The heeling lever due to the shift of fodder in pellet form carried in bulk at 40° is to be given by 0.8 (heeling lever due to the shift of fodder at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

Section 4 PROVISION OF LIVESTOCK SERVICES

2.4.1 General requirements

2.4.1.1 Facilities or systems providing daily services for livestock are to be fitted in livestock spaces and these facilities or systems intended for:

(1) the supply of food, water and fresh air to the livestock;

(2) the cleaning of the livestock spaces;

(3) the draining and outside discharging of the sewage effluents produced by the livestock.

2.4.1.2 In addition to the provisions of this Section, the piping is to comply with the applicable requirements of Chapter 2 and Chapter 3, PART THREE of the Rules.

2.4.2 Ventilation system

2.4.2.1 An enclosed space for the carriage of livestock is to be provided with a mechanical ventilation system of sufficient capacity to change the air of that space in its entire volume as follows:

(1) if the minimum clear height of the space is 2.30 m or more, not less than 20 changes per hour;

(2) if the minimum clear height of the space is 1.80 m, not less than 30 changes per hour; and

(3) if the minimum clear height of the space is between 2.30 m and 1.80 m, at a rate proportional to those specified above. This may be obtained by linear interpolation.

For the purposes of this paragraph, the volume of an enclosed space includes all that space contained between the vessel's side plating, bulkheads, tank top or decks enclosing the space, less the volume of any tanks or trunks that are airtight within the space and no deduction is to be made in respect of space occupied by livestock, pens or other livestock fittings.

2.4.2.2 A space for the carriage of livestock that is not enclosed is to be provided with a mechanical ventilation system if:

(1) the space, being a structure having an arrangement of pens on more than one deck level, has a breadth greater than 20 m; or

(2) because of a partial enclosure of the space, the natural ventilation is restricted.

The capacity of ventilation system is to comply with the requirements in paragraph 2.4.2.1.

The volume of a space that is not enclosed referred to in this paragraph includes all that space contained between the extremities of a pen structure including passageways on the outboard sides or ends of the structure, less the volume of any tanks or trunks that are airtight within the pen structure and no deduction is to be made in respect of space occupied by livestock, pens or other livestock fittings.

2.4.2.3 A mechanical ventilation system is to distribute air so as to ensure that the whole of each livestock space is efficiently ventilated.

2.4.2.4 Ventilation circuits are to be supplied by at least two independent fans of such a capacity as to maintain the ventilation of all the spaces as required by 2.4.2.1 and 2.4.2.2 with one fan out of action. Notwithstanding the above provisions, if a mechanical ventilation system is provided with adequate spare parts, the provision of only one fan is acceptable. Adequate spare parts are to be interpreted as including for each type of fan: one set of bearings; one rotor or impeller; and one complete motor.

2.4.2.5 Electrical supplies from both main and secondary sources of power are to be supplied to each group starter panel, with both supplies being as widely separated as practicable and neither passing through any space containing any part of the other source of power. Interlocks at each group starter are to prevent simultaneous supply by both sources of power.

2.4.2.6 If two or more independent fans are fitted in the ventilation piping of each space, fan group starter panels are to be located in at least two locations, with the operation of fans from either panel being able to effectively ventilate the required livestock spaces.

2.4.3 Fodder and Water arrangements

2.4.3.1 Spaces intended for livestock (including pens, stalls or similar fittings) are to be provided with receptacles for feeding and watering the animals concerned.

2.4.3.2 The receptacles are to be capable of containing at least 33 per cent of the daily allowance of fodder and water for the number of animals contained in the space (pen, stall or similar fitting) except where the fodder or water is provided by an automatic system.

2.4.3.3 A receptacle provided in accordance with 2.4.3.1 and 2.4.3.2 above is to be:

(1) suitable for the species of livestock;

(2) readily accessible to the livestock;

(3) capable of being serviced from outside the pen, stall or other fitting;

(4) so installed as to not impede ventilation; and

(5) so constructed and positioned, that fodder dust is not disturbed by the flow of ventilation.
2.4.3.4 If the fodder distribution system is dependent on electric power, the system is to be capable of being powered by both the main and secondary sources of supply.

2.4.4 Fresh water system

2.4.4.1 All livestock spaces are to be provided with fresh water service.
2.4.4.2 The fresh water system is to include one main supply pump and one standby pump, of a capacity sufficient to continuously supply fresh water to the livestock.
When the water supply system is not automatic, the standby pump may be replaced by a portable pump ready to be connected to at least one fresh water tank.
2.4.4.3 If the fresh water system is dependent on electric power, it is to be powered by both the main and secondary sources of power and can continue to operate despite a fire or other casualty in the space containing the main source of power. One pump may be located in the space occupied by the main source of power and supplied by that source of power. The other is to be able to maintain supply despite a fire or other casualty affecting the space occupied by the main source of power.
2.4.4.4 When the water supply is automatic, water receptacles are to be fitted with means of automatic water level control and devices to avoid the return of water from the receptacle to the fresh water tank.
2.4.4.5 The fresh water system serving the livestock spaces is to be totally independent from the fresh water system serving the spaces intended for the crew.

2.4.5 Water washing system

2.4.5.1 A water washing system is to be provided with appropriate connections to wash the livestock spaces.

2.4.6 Drainage and discharge of sewage

2.4.6.1 Each space intended for the livestock is to be fitted with a pipe or gutter of sufficient size to drain the sewage and the washing effluents.
2.4.6.2 Drainage arrangements are to be such that fluids drained from a pen are as far as practicable kept clear of other pens and associated working and access spaces.
Where necessary, drainage gutters and upper parts of the draining pipes are to be covered by a strainer plate. In addition, drainage pipelines are to be so arranged that the drainage system can still be used with the ship's trim by bow or stern.
2.4.6.3 The drainage system serving the livestock spaces is to be independent from any piping system serving the other spaces of the ship, and in particular from the bilge system.
2.4.6.4 The pipes and other components of the draining system are to be made of a material resistant to the corrosion due to the effluents.
2.4.6.5 Essential drainage tanks, wells and the top of drainage pipes in a vessel are to be accessible from outside livestock pens for the purpose of inspection and cleaning.
2.4.6.6 Pumps and ejectors serving the drainage tanks or wells are to be capable of conveying semi-solid matter.
2.4.6.7 All electrical equipment fitted to meet the requirements of 2.4.6 are to be capable of being operated by both the primary and the secondary sources of power.

Section 5 FIRE-FIGHTING APPLIANCES

2.5.1 Fire hydrants and fire hoses

2.5.1.1 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant may reach any part of the spaces intended for the livestock. At least one of these jets is to be from a single length of hose without the necessity for hoses to pass over or through pens.
2.5.1.2 A fire hose is to be provided in an enclosed space for each hydrant and in any other space or on a deck for each 50 m length, or part thereof, of space or deck.
2.5.1.3 Each fire hose is to be provided with the necessary connections and a nozzle capable of directing water in the form of a spray and a jet.
2.5.1.4 Each hose is to be capable of being connected to any hydrant and to any other hose (other than hydrants and hoses within the engine room or accommodation spaces).
2.5.1.5 Fire hoses are to be located in conspicuous locations, near the hydrants and close to the entrances or access to the spaces.

2.5.2 Additional fire-fighting means

2.5.2.1 Livestock structures, including livestock decks and containment structures but excluding livestock services such as water pipes and feed troughs, are to be constructed of non-combustible materials.

2.5.2.2 If hay or straw is carried or used in a livestock space, one of the following fire-fighting means is to be provided:

(1) a fixed water fire-fighting system, or

(2) portable water extinguishers spaced not more than 18 m apart, one of which being positioned at the entrance of the space concerned.

2.5.2.3 Where electrical equipment other than that referred to in Section 6 of this Chapter is located in an enclosed livestock space, suitable fire-fighting means are to be provided in this respect.

Section 6 ELECTRICAL EQUIPMENT

2.6.1 General requirements

2.6.1.1 In addition to the applicable requirements of PART FOUR of the Rules, electrical equipment of livestock carriers is to comply with the provisions of this Section.

2.6.2 Sources of electrical power for livestock carriers

2.6.2.1 The main source of power is to meet the following:

The main source of power as specified in 2.1.1.1 of Chapter 2, PART FOUR of the Rules is to be provided and all electrical auxiliary services (including livestock services) necessary for maintaining the livestock carrier in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power.

2.6.2.2 The secondary source of power is to meet the following requirements:

(1) The secondary source of power is to be located in a space that is not contiguous with any space containing the main source of power or part thereof, and be independent of any services provided from or through any such space. In case of a fire or other casualty in any space containing the main source of power or any part thereof, the secondary source of power must be capable of supplying power to livestock services for a period of 72 h.

(2) The prime mover of secondary source of power is to be capable of supplying power to the system within 30 min in the failure of main source of power. The prime mover may be started by an effective arrangement powered by an independent source of energy or the emergency source of power complying with the requirements of paragraphs 1.1, 1.4 and 2 of SOLAS regulation II-1/43.

(3) Instructions are to be provided for the changeover between main and secondary sources of power and vice-versa. A copy of such instructions is to be posted in the space containing the livestock source of power, and is to be readable under the emergency lighting required by SOLAS regulation II-1/43.2.2. The instructions are to detail, among other things, starting method, switchboard changeover and electrical supply changeover to livestock services.

(4) Cables of secondary source of power are to be kept away from cables of main source of power in so far as practicable and generally they do not pass through the same space.

2.6.3 Lighting

2.6.3.1 Livestock spaces, passageways between pens and access routes between or to those spaces are to be adequately lit.

2.6.3.2 An emergency lighting system that is automatically activated on the failure of the main electrical installation is to be provided in all parts of a vessel where livestock is carried, passageways between pens and access routes between or from those parts, and is to be capable of giving a level of illumination in all passageways and access routes for a continuous period of not less than 15 min. The lamp casings on light fittings for the emergency lighting system are to be painted red for ease of identification.

2.6.3.3 If fixed lighting is provided in a part of a vessel above the uppermost continuous deck, that lighting is to be capable of being controlled from the navigating bridge.

2.6.3.4 Light fittings is to be of sufficient strength and fitted with protective sheathing outside to resist damage by livestock and placed beyond possible contact by livestock.

2.6.4 Electrical equipment for use in dust laden atmospheres

2.6.4.1 Electrical equipment and cables installed in areas where flammable dusts may be present (such as spaces used for the storage or handling of bulk fodder) are to comply with the requirements of 2.18.3.2 of Chapter 2, PART FOUR of the Rules.

2.6.4.2 Lighting, or power points for portable lighting, in a space used for carriage of fodder in bulk, are to be controlled by switches situated on the navigating bridge or at the fodder-handling machinery control station and indicator lights are to be provided to show when power is supplied to the lighting or power points.

CHAPTER 3 ADDITIONAL REQUIREMENTS FOR OIL RECOVERY SHIPS

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 The requirements of Sections 1 to 5 of this Chapter apply to steel ships equipped for the recovery of oil floating on the sea with a flash point not exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure, as required for the class notations in paragraphs 3.1.2.1 and 3.1.2.2.

The requirements of Section 6 of this Chapter apply to steel ships equipped for the recovery of oil floating on the sea with a flash point exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure, as required for the class notation in paragraph 3.1.2.3.

3.1.1.2 The ship is to be capable of the following operations at a safe distance from the source of oil spill:

(1) recovery of floating oil from the surface of the sea;

(2) handling, storage and transportation of the recovered oil.

3.1.1.3 The other auxiliary ships associated with operations of oil recovery ships may be dealt with by referring to this Chapter.

3.1.2 Class notations

3.1.2.1 Oil recovery ships equipped with means for the recovery and discharge of oil as well as with tanks for storing the recovered oil and complying with the requirements of Sections 1 to 5 of this Chapter will be assigned the class notation Oil Recovery Ship with Cargo Tank.

3.1.2.2 Oil recovery ships without tanks for storing the recovered oil equipped with means for the recovery, but not for discharge of oil and complying with the requirements of Sections 1 to 5 of this Chapter will be assigned the class notation Oil Recovery Ship without Cargo Tank.

3.1.2.3 Oil recovery ships equipped with means for the recovery of oil and complying with the requirements of Section 6 of this Chapter will be assigned the class notation Oil Recovery Ship not suitable for products with a flash point of 60℃ and less.

3.1.3 Definitions

3.1.3.1 Oil recovery ship means a steel ship specially or also engaged in the recovery of oil floating on the sea.

3.1.3.2 Gas-hazardous zone means an area in which flammable or explosive gas or vapor is liable to accumulate to a dangerous concentration. The gas-hazardous zones may be divided into the following categories:

(1) Hazardous zone of Category 0 means an area in which the mixture of flammable or explosive gas or vapor with air exists continuously or for long time.

(2) Hazardous zone of Category 1 means an area in which the mixture of flammable or explosive gas or vapor with air may occur during normal operation.

3.1.3.3 Source of oil spill means the source from which the oil floating on the sea originates, e.g. from an oil tanker, a submarine oil pipeline or an offshore drilling unit.

3.1.4 Division of gas-hazardous zones and safe areas

3.1.4.1 The following areas or spaces of oil recovery ships are to be regarded as gas-hazardous zones:

(1) Hazardous zones of Category 0:

① recovered oil tanks;

② the interiors of piping systems and containers of the containment system for recovered oil.

(2) Hazardous zones of Category 1:

① cofferdams or other spaces adjacent to any recovered oil tank (except for 3.2.2.6);

② enclosed or semi-enclosed spaces in which pipe flanges, valves, hoses, pumps and other equipment for handling of recovered oil are located;

③ spaces including semi-enclosed spaces on open deck within a 3 m radius of the separator, the hoses and valves used for oil recovery, the openings of recovered oil tanks and the openings of spaces within the hazardous zones of Category 1 such as recovered oil pump rooms or cofferdams. In addition, the relevant provisions for venting outlets of covered oil tanks are to be considered (refer to 3.3.3.2 of this Chapter);

④ space on open deck above recovered oil tanks, extending 3 m respectively fore and aft of this area to a height of 2.4 m;

⑤ any enclosed space outside a recovered oil tank, through which recovered oil piping passes or in which such piping terminates, may be excluded, provided that ventilation is fitted as specified in 3.2.5.4 of Section 2;

⑥ enclosed or semi-enclosed spaces which can be entered directly from hazardous zones of Category 1 (without air lock) or which have openings into hazardous zones of Category 1 may be excluded, provided that ventilation is fitted as specified in 3.2.5.4 of Section 2.

3.1.4.2 The areas outside the above-mentioned gas-dangerous zones are safe areas.

3.1.5 Plans and documents

3.1.5.1 The relevant plans and documents as specified in the relevant chapters of the Rules and in addition, the following ones are to be submitted for approval:

(1) General arrangement of equipment for oil recovery operations;

(2) Details of access doors (including air locks) and openings used in normal recovery operations and not fitted with gastight sealing;

(3) Details of access doors and openings closed gastight in oil recovery operations;

(4) Details of arrangement and capacity of recovered oil tanks;

(5) Division of gas-hazardous zones;

(6) Drawing of power system of the equipment used for oil recovery operations;

(7) Details of arrangement of piping, pumping and handling systems for recovered oil;

(8) Arrangement of venting system of recovered oil tank;

(9) Arrangement of electrical equipment in gas-hazardous zones;

(10) Operating manual (see Section 5 of this Chapter);

(11) Other plans and documents as deemed necessary.

Section 2 CONSTRUCTION AND FIRE SAFETY

3.2.1 Hull structures

3.2.1.1 The structures of oil recovery ships are to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

3.2.1.2 For integral recovered oil tanks, the thickness of the plane oiltight bulkhead plating is to comply with the requirements of 3.2.1.3 and 3.2.1.4, and other structural members of bulkhead are to comply with the relevant requirements of Chapters 5 and 6, PART TWO of the Rules.

3.2.1.3 The thickness t of the plane oiltight bulkhead plating of integral recovered oil tanks is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{h} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, from lower edge of the plate in a strake to the tank top, but not less than $0.4D$.

3.2.1.4 The thickness t of the plane oiltight bulkhead plating of integral recovered oil tanks is also to comply with the following requirements:

(1) Where vertical stiffeners are fitted on the bulkhead:

$t \geq s/86$ mm, for the upper 3/4 of the bulkhead

$t \geq s/74$ mm, for the lower 1/4 of the bulkhead.

(2) Where horizontal stiffeners are fitted on the bulkhead:

$t \geq s/98$ mm, for the upper 3/4 of the bulkhead

$t \geq s/84$ mm, for the lower 1/4 of the bulkhead

where: s — spacing of stiffeners, in mm.

3.2.2 Arrangement of recovered oil tanks

3.2.2.1 Any tanks, which are also intended for other purposes and will not be utilized during oil recovery operations, are to be arranged so that recovered oil cannot be transferred to them inadvertently.

3.2.2.2 The position of tanks for recovered oil is to satisfy the following requirements:

(1) they are to be located outside the accommodation and machinery spaces;

(2) they are not to be located below the accommodation and machinery spaces;

(3) they are to be located forward or aft of the accommodation and machinery spaces of category A.

3.2.2.3 Except where permitted by 3.2.2.6, tanks for recovered oil are to be separated from accommodation and machinery spaces by cofferdams. Oil fuel tanks, settling tanks, tanks for ballast water or anti-pollution liquid, enclosed spaces where oil recovery handling equipment is stored, pump rooms for recovered oil and dry compartments other than accommodation spaces may be considered as a cofferdam. When oil fuel tanks or settling tanks are used as cofferdams, only one common boundary can be provided between each oil fuel tank or settling tank and the tank for recovered oil. The continuous butt welding is to be used for the bulkhead plating of the common boundary. Full penetration welding is to be used for the fillet weld at the connection of the bulkhead to the deck.

3.2.2.4 Cofferdams are to be at least one frame spacing in length (600 mm minimum) and are to cover the whole area of the boundary under consideration.

3.2.2.5 The height of tanks for recovered oil is not to be less than 1.5 m. Internal obstructions in the tanks are to be avoided to ensure a full flow of recovered oil. Adequate drainage openings are to be provided to ensure free flow of residues to assist in cleaning and gas freeing on completion of recovery operations. Any coating in the walls of tanks for recovered oil is to be of an oil and dispersion resistant type.

3.2.2.6 Where cofferdams are impractical to arrange in accordance with the requirements of 3.2.2.3 on board, any tank adjacent to other machinery spaces (except for machinery spaces of category A) or pipe tunnel may be accepted for storage of recovered oil, provided that:

(1) tank bulkheads are easily accessible for inspection;

(2) the continuous butt welding is to be used for the bulkhead plating, except that full penetration welding is used for the fillet weld at the connection of the bulkhead to the deck;

(3) other machinery spaces or pipe tunnels are to be fitted with mechanical ventilation giving at least 20 air changes per hour (calculated based on the tank capacity) and alarms for ventilation failure. The number of air changes required above is to be maintained in case of failure of any ventilation fan. Ventilation fans are to be of non-sparking type. The electric motor fitted in the ventilation duct is to be of certified safe type;

(4) tanks are to be subject to hydraulic testing at special surveys;

(5) the common boundary of tanks is to be subject to thickness measurement at special surveys if necessary.

3.2.2.7 All openings (sounding pipes, hatches for the deployment of portable recovered oil pumps and hoses) to tanks for recovered oil are to be located on open deck to prevent accumulation of oil vapour.

3.2.2.8 Tanks for recovered oil are to have suitable access from open deck for cleaning and gas-freeing, or small dedicated hatches for cleaning.

3.2.2.9 Tanks for recovered oil are in general to be provided with wash bulkheads in one of the following cases:

(1) 0.5*B* (*B* being breadth of the ship) is exceeded; or

(2) 0.1*L* (*L* being length of the ship) or 10 m is exceeded, whichever is the greater.

3.2.3 Access and other openings

3.2.3.1 Ventilation openings to safe spaces such as accommodation, service and machinery spaces, control stations and navigation bridge are not to be located inside gas-hazardous zones.

3.2.3.2 In general, no access door or any opening other than access openings and ventilation openings is to be permitted between safe spaces (such as accommodation, service and machinery spaces, control stations and navigation bridge) and gas-hazardous zones.

(1) Access doors may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① an air lock is to consist of two steel doors substantially gastight which are to be spaced not less than 1.5 m apart (watertight doors may be considered as gastight doors);

② safe spaces are under positive pressure mechanical ventilation in relation to the gas-hazardous zones;

③ the doors are to be self-closing and without any holding back arrangements;

④ signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks.

(2) Any opening other than access openings and ventilation openings may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① the closing appliance is to be confirmed as gastight;

② signs are provided to warn that they are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.

3.2.3.3 Where the access doors mentioned in 3.2.3.2 above are not used as the means of escape specified in statutory requirements and they will not be used (opened) during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks (including accidental and emergency conditions the ship might encounter during the operations), air locks may not be fitted. In addition to complying with the requirement that the doors are to be self-closing and without any holding back arrangements, the following requirements are at least to be met:

(1) gastight closing can be achieved, which has been confirmed;

(2) signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.

3.2.3.4 Oil handling spaces on deck are to be provided with a coaming around all recovered oil pumps, transfer flanges and other connections. Each coaming is to have a height sufficient to prevent recovered oil from entering accommodation, machinery, control and service spaces or passing overboard. The coaming is to have a height of at least 150 mm. Where drains are provided for the coaming, closing devices for these drains are to be permanently attached.

3.2.4 Fire protection and extinction

3.2.4.1 For vessels with tanks for recovered oil forward of superstructures, exterior boundaries of superstructures and deckhouses enclosing accommodation, including any overhanging decks which support such accommodation, are to be insulated to A-60 class standard for all parts which face deck areas where there are arrangements for collection, handling and transfer of recovered oil as well as exterior surfaces within 3 m from the ends of boundaries facing these areas. The requirement is also applicable for access doors in such boundaries.

3.2.4.2 For vessels with tanks aft of superstructures, exterior boundaries of superstructures and deckhouses enclosing accommodation, situated within 10 m of the nearest tank for recovered oil, including any overhanging decks which support such accommodation, are to be insulated to A-60 class standard for all parts which face deck areas where there are arrangements for collection, handling and transfer of recovered oil as well as exterior surfaces within 3 m from the ends of boundaries facing these areas.

3.2.4.3 Portholes or windows in the exterior boundaries which are required to be insulated to A-60 class standard, as referred to in 3.2.4.1 of this Section, are to be of fixed (non-opening) type and are to be insulated to A-60 class standard, except for those in the navigation bridge.

3.2.4.4 As an alternative to compliance with 3.2.4.1 and 3.2.4.2, a fixed water spraying system may be used to protect all boundaries, portholes or windows which may, in this case, be insulated to A-0 class standard. The system is to be capable of delivering water at a rate of 10 *l*/min per m^2 at least and is to be readily available.

3.2.4.5 Working deck areas used for oil recovery operations, where there are arrangements for the collection, handling and transfer of recovered oil, are to be provided with the following fire-extinguishing equipment:

(1) two dry powder fire-extinguishers, each at least 50 kg capacity. The fire-extinguishers are to be located near the working deck and are to be fitted with discharge hoses having a length sufficient to reach the arrangements for the collection, handling and transfer of recovered oil;

(2) a large fire-extinguishing foam installation fitted with at least one portable foam applicator. The foam installation is to be so arranged that it is capable of applying foam to any part of the working deck. The capacity of any applicator is to be not less than 400 *l* /min of foam solution and the applicator throw in still air conditions is to be not less than 15 m. Sufficient foam concentrate is to be provided for at least 0.4 *l* /m^2 of the working deck area with a minimum quantity of 200 *l*. The foam expansion ratio is generally not to exceed 12 to 1.

3.2.4.6 Each recovery oil pump-room is to be provided with a fixed fire-extinguishing system suitable for machinery spaces of category A. The system controls are to be operated from a readily accessible position outside the pump-room. Where a carbon dioxide system is used, the quantity of carbon dioxide is to be sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the tanks for recovered oil. A notice is to be exhibited at the controls stating that, due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes.

3.2.4.7 Oil recovery ships are to carry at least four fire-fighter's outfits.

3.2.5 Mechanical ventilation

3.2.5.1 The design, type and structure of mechanical ventilation systems may be dealt with in accordance with the relevant requirements for oil tankers.

3.2.5.2 Spaces with access to hazardous zones of Category 1 are to be kept under positive pressure mechanical ventilation during oil recovery operations, with the air intake located inside a safe area.
3.2.5.3 Spaces in hazardous zones of Categories 0 and 1 that are not frequently used during oil recovery operations are not to be ventilated, provided that the equipment therein is provided with the required explosion protection. For safety reasons, spaces in hazardous zones of Categories 0 and 1 that must be accessible at all times are to be equipped with a ventilation system of the extraction type, ensuring at least 8 air changes per hour.
3.2.5.4 Hazardous zones of Category 1 as specified in 3.1.4.1(2)⑤, ⑥ of Section 1 of this Chapter may be accepted as safe areas, provided that the following special ventilation requirements are complied with and positive pressure mechanical ventilation is maintained:
(1) the ventilation airflow is to be at least 20 air changes per hour;
(2) the arrangement of ventilation inlet and outlet openings in a space is to be such that the entire space is efficiently ventilated, taking special consideration to locations where gas may be released or may accumulate;
(3) the air intake is to be located in a safe area.
3.2.5.5 For the spaces required to be under positive pressure ventilation, audible and visual alarms are to be initiated at the navigation bridge or other suitable positions in case of loss of positive pressure ventilation.

3.2.6 Gas detection and alarm system

3.2.6.1 For the purpose of explosion protection, the ship is to be equipped with a permanently installed gas detection system, which will actuate an audible and visual alarm at the navigation bridge, open deck or other suitable positions when a concentration of hydrocarbon gas or similar products equal to 30% of the lower explosion limit (LEL) is exceeded.
Detection points may be arranged according to specific circumstances, generally close to ventilation air intakes, in air locks and on the main deck (at least one at the fore end and one at the aft end of the ship).
3.2.6.2 In addition to the above gas detection system, at least one portable instrument is to be available on board for gas detection.

Section 3 MACHINERY INSTALLATIONS

3.3.1 General requirements

3.3.1.1 All machinery equipment used in gas-hazardous zones during oil recovery operations is to be suitable for operation in gas contaminated atmosphere.
3.3.1.2 The exhaust lines of diesel engines, the flue ducts of boilers and the vents of diesel engine crankcases are to be led to a position outside the gas-hazardous zones as described in 3.1.4 of Section 1.
3.3.1.3 The exhaust lines of diesel engines and the flue ducts of boilers are to be provided with effective spark arresters.

3.3.2 Transfer system for recovered oil

3.3.2.1 A fixed transfer system for recovered oil is to be provided. The transfer system is to be arranged such that simultaneous filling and discharge will be possible. Unless provided otherwise, the transfer system for recovered oil is to be independent of all other piping systems onboard.
3.3.2.2 For coupling of portable skimming equipment, one or maximum two filling connections with branch pipes to all recovered oil tanks are to be arranged on deck.
3.3.2.3 Where recovered oil transfer pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump room plating. The glands are to be capable of being lubricated from outside the pump room and are to be so designed as to prevent overheating. The seal parts of the glands are to be of materials that will not initiate sparks. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 0.34 MPa before being fitted.
3.3.2.4 All recovered oil transfer pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump, and to effectively limit the pump discharge pressure to the design pressure of the system.
3.3.2.5 One pressure gauge for each recovered oil transfer pump is to be located at the pump discharge and, where the pumps are capable of being operated from outside the pump room, an additional gauge is to be provided which is to be visible from the operating station.

3.3.2.6 Piping systems related to oil recovered are to be arranged as follows:
(1) piping systems related to oil recovered are not to pass through machinery and accommodation spaces;
(2) piping systems related to oil recovered are not to pass through drinking water tanks, boiler water tanks or other tanks. Where it is unavoidable for piping systems to pass through other tanks, the portions of pipelines within tanks are to be all-welded extra thick pipes without valves, flanges, fittings or slip joints (see for wall thickness requirements in Table 5.3.4.2 of Chapter 5, PART THREE of the Rules).

3.3.3 Venting arrangements of tanks for recovered oil

3.3.3.1 Every tank for recovered oil is to be fitted with a vent pipe or other equivalent venting arrangement. The vent pipes are to be sized for 125% of the maximum loading rate to prevent the pressure in any recovered oil tank from exceeding the design pressure; however, the diameter of each vent pipe is to be not less than 60 mm. Venting outlets are to be led to open deck. Gas from the outlets is to be discharged directly upwards.
3.3.3.2 The outlets are to have a minimum height of 2.4 m above deck and be located at a minimum horizontal distance of 5 m away from openings to accommodation and other gas-safe spaces, ventilation intakes for accommodation and machinery spaces and non-certified safe electrical equipment.
3.3.3.3 The end of vent pipes is to be fitted with a corrosion resistant flameproof wire gauze capable of being easily renewed.
3.3.3.4 Vent pipes are also to comply with the applicable requirements of Chapter 3, PART THREE of the Rules.
3.3.3.5 For multi-purpose oil recovery ships, portable vent pipes intended for use during oil recovery operations only, may be accepted.

3.3.4 Other systems related to recovered oil

3.3.4.1 Tanks for recovered oil are to be fitted with suitable means for determining the level within the tanks. Sounding pipes, if fitted for this purpose, are to terminate in the open air above freeboard deck. The internal diameter of sounding pipes is not to be less than 50 mm.
3.3.4.2 Provisions are to be made to guard against liquid rising in recovered oil tanks to a height which would exceed the design head of the tanks. This may be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and tank filling procedures. The high level alarm is to be capable of giving an audible and visual alarm at the recovered oil control station.
3.3.4.3 The heating systems and other steam pipelines fitted to recovered oil tanks are to comply with the relevant requirements of Chapter 5, PART THREE of the Rules.
3.3.4.4 Bilge drainage of the recovered oil transfer pump room and the cofferdam within the gas-hazardous zones is to be effected by powered pumps or bilge ejector suctions independent of the bilge drainage system of safe spaces. The pump room bilge is to be drained into the tanks for recovered oil.
For oil recovery ships of not more than 500 gross tons, the pump room bilge may be drained by a hand pump having at least a 50 mm bore suction.
3.3.4.5 The ballast piping system serving gas-hazardous zones is to be independent of that serving safe spaces. The ballast pump is to be located in the recovered oil pump room or other suitable gas-hazardous space.

3.3.5 Machinery equipment and systems in gas-hazardous zones

3.3.5.1 The oil recovery equipment and hoses are to be electrically bonded into the ship's hull. The cross-sectional area of the metallic bonding strap is to be not less than 10 mm^2.
3.3.5.2 Hoses are to be electrically well conductive.
3.3.5.3 No sparks are allowed during operation of the oil recovery equipment.
3.3.5.4 Surface temperature of the equipment is not to exceed 200℃.

Section 4 ELECTRICAL INSTALLATIONS

3.4.1 General requirements

3.4.1.1 Unless specified otherwise in this Section, electrical equipment, cables and distribution systems are to comply with the relevant requirements of Section 16, Chapter 2 of PART FOUR of the Rules.
3.4.1.2 The equipment used for oil recovery operation and deck areas used for storing hoses are to have adequate lighting.

3.4.1.3 The power distribution systems of oil recovery ships having the notation Oil Recovery Ship without Cargo Tank are to comply with Section 4, Chapter 2 of PART FOUR of the Rules.

3.4.2 Electrical equipment in gas-hazardous zones

3.4.2.1 The use of electrical appliances in gas-hazardous zones as specified in 3.1.4 of Section 1 is to be restricted to operationally essential equipment and is to comply with Table 3.4.2.1.

Electrical Equipment Permitted in Gas-Hazardous Zones Table 3.4.2.1

Category of hazardous zones	Type of electrical equipment	Cable
0	Intrinsically safe Ex" ia"	Cables associated with intrinsically safe equipment in such zones
1	Intrinsically safe Ex" ia", Ex" ib"	Cables associated with the equipment in such zones; through runs of cables
	Flameproof Ex" d"	
	Increased safety Ex" e"	
	Pressurized enclosure Ex" p"	
	Powder filled Ex" q"	
	Encapsulated Ex" m"	

3.4.2.2 The explosion-proof electrical equipment listed in Table 3.4.2.1 is to meet at least the following requirements:

Temperature class T3;

Equipment group II A.

3.4.2.3 All equipment not complying with 3.4.2.1 of this Section and located in the gas-hazardous zones as specified in 3.1.4 of Section 1 are to be disconnected during oil recovery operation. The switches for such disconnection are to be safeguarded against unintentional re-connection and appropriately marked to that effect.

3.4.2.4 The flexible cables without armor or metal braid may be applied in zones of Category 1, provided that the construction and installation of such cables are to comply with acceptable standards①, as appropriate.

3.4.2.5 Portable oil recovery equipment and recovered oil pumps are to comply with the following requirements:

(1) Portable oil recovery equipment and recovered oil pumps are to be supplied from a permanently installed distribution box or socket outlet.

(2) Socket outlets for power circuits are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

(3) The socket outlet as the separate final sub-circuit is to be provided with a circuit breaker capable of overcurrent and short-circuit protection in each insulated phase. The supply to the socket-outlet is to be permanently installed.

(4) Socket outlets are to be located at easily accessible places and in such a way that flexible cables are not carried through doors or portlights leading from working deck to machinery or accommodation spaces.

Section 5 OPERATING MANUAL

3.5.1 Operating manual

3.5.1.1 The ship is to be provided with an approved operating manual. In general, the operating manual is to contain a description of the safety precautions needed when preparing for and carrying out oil recovery operations.

3.5.1.2 The operating manual for oil recovery ships is to include:

(1) Equipment and arrangement

① arrangement of recovered oil tanks;

② transfer system for recovered oil;

③ gas-measuring instrument;

④ other associated units of equipment.

(2) Preparations for operation

---

① Refer to IEC publication 60079-14: Explosive atmospheres – Part 14: Electrical installations design, selection and erection.

① checking all equipment on board to determine compliance with 3.3.1.1 of Section 3 and 3.4.2.1 of Section 4;
② mounting and fastening of non-permanent equipment;
③ blanking off particular pipes;
④ assembling air pipes;
⑤ disconnecting power supply to those electrical installations not complying with 3.4.2.1 of Section 4;
⑥ closing openings between safe areas and gas-hazardous zones;
⑦ starting up additional ventilation equipment;
⑧ changeover to low suction for cooling water pumps;
⑨ displaying signs to the effect that open flame, non-certified explosion-proof electrical equipment, etc. are prohibited.

(3) Oil recovery operation
① guidance on safe distance from an oil spill source and relevant notes;
② gas measurements during operation (on open deck and in spaces where gas may accumulate). If gas is traced on open deck, the ship is to move away immediately;
③ actions to be taken for cleaning, ventilation, emptying adjacent tanks, etc., if gas is traced in any enclosed space;
④ emergency measures to be taken in case of failure of positive pressure ventilation;
⑤ precautions against overfilling of recovered oil tanks;
⑥ discharging.

(4) Cleaning and gas-freeing of recovered oil tanks and pipes.

Section 6 OIL RECOVERY SHIPS CARRYING RECOVERED OIL HAVING A FLASH POINT EXCEEDING 60℃

3.6.1 General requirements

3.6.1.1 Ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the relevant requirements of Sections 1 (excluding paragraph 3.1.4) and 5 of this Chapter, and the following additional requirements.

3.6.2 Construction and fire safety

3.6.2.1 Ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the requirements of Chapter 2, PART TWO of the Rules.

3.6.2.2 The fire safety of ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the relevant requirements for cargo ships and the following additional requirements:

(1) In working deck areas, fire-extinguishing equipment required in 3.2.4.5 of this Chapter is to be provided in lieu of the fixed fire-extinguishing system required for cargo spaces of cargo ships.

(2) All openings of tanks for recovered oil are to be located in accordance with the requirements of 3.2.2.7 of this Chapter.

(3) Spill coamings and drains are to be provided in accordance with the requirements of 3.2.3.4 of this Chapter.

(4) Fire-fighter's outfits are to be provided in accordance with the requirements of 3.2.4.7 of this Chapter.

(5) At least one portable instrument is to be available on board for gas detection.

3.6.3 Machinery installations

3.6.3.1 For ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃, paragraphs 3.3.2.1, 3.3.2.2, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.4.1, 3.3.4.2 and 3.3.4.3 of this Chapter are applicable. However, subparagraph 3.3.2.6(1) may be replaced by the following:

(1) piping systems related to oil recovered are not to pass through machinery and accommodation spaces as far as practicable; where this is unavoidable, the arrangement of such piping systems within machinery spaces is to comply with the requirements for fuel oil piping systems.

3.6.3.2 The venting arrangements of tanks for recovered oil are to comply with the requirements of 3.3.3 of this Chapter, or the requirements for fuel oil tanks in Chapter 3, PART THREE of the Rules.

3.6.4 Electrical installations

3.6.4.1 The additional requirements for electrical installations of ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to be in compliance with 2.16.7 of Section 16, Chapter 2, PART FOUR of the Rules.

CHAPTER 4 SHIP BRIDGE DESIGN AND EQUIPMENT

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This Chapter applies to ships applying for the notations as specified in 4.1.2 of this Chapter..

4.1.1.2 The provisions of this Chapter are not to prevent the ship from complying with the relevant IMO conventions, codes and requirements of the Administration of the Flag State.

4.1.2 Notations

4.1.2.1 Ships of which bridge design and equipment installed complying with the following provisions may be assigned with the following notations upon application:

(1) BDE-1 is applicable to ships complying with the basic design requirements, working environment and the required equipment to be installed in Sections 1 to 5 of this Chapter;

(2) BDE-2 is applicable to ships complying with the requirements in Sections 1 to 6 of this Chapter;

(3) BDE-3 is applicable to ships of which the bridge is fitted with the Integrated Bridge System (IBS) complying with requirements in Sections 1 to 7 of this Chapter.

4.1.3 Definitions

4.1.3.1 For the purpose of this Chapter:

(1) Workstation means position at which one, or several tasks constituting a particular activity are carried out.

(2) Navigator means person navigating, operating bridge equipment and manoeuvring the ship.

(3) Back-up navigator means any individual, generally an officer, who has been designated by the ship's master to be on call if assistance is needed on the navigation bridge.

(4) Officer of the watch means person responsible for operating of bridge equipment and manoeuvring of the ship.

(5) Bridge means that area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings.

(6) Wheelhouse means enclosed area of the bridge.

(7) Bridge wings are those parts of the bridge on both sides of the ship's wheelhouse which, in general, extend to the ship's side.

(8) Field of vision means angular size of a scene that can be observed from a position on the ship's bridge.

(9) Lookout means activity carried out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

(10) Watch alarm means alarm that is transferred from the bridge to the master and the back-up navigator in case of any officer of the watch deficiency (absence, lack of alertness, no response to another alarm/warning, etc.).

(11) Workstation for navigation manoeuvring means a workstation with a commanding field of vision used by a navigator during course monitoring, traffic monitoring, course change and speed change, which can monitor the ship's safety condition.

(12) Workstation for monitoring means a workstation that facilitates the operation of equipment and observation of the ship's heading, speed, water and traffic with a commanding field of vision, including means necessary for route monitoring, to be used by the officer of the watch, backup navigator or pilot as needed for effective bridge team operation. The station may be considered as part of the workstation for navigation manoeuvring when paper charts or ECDIS are used for route monitoring.

(13) Workstation for manual steering means a workplace where the helmsman manually controls the ship's required ield of vision, indicators and equipment according to the instructions given by the navigator in charge of bridge operation.

(14) Workstation for docking means a workplace on the bridge wing that provides the field of vision and information required to control ship manoeuvring, tug operation and mooring operation along the berth.

(15) Workstation for plan development means a workplace used to plan the route of the entire voyage from place of departure to place of destination and to record the bridge operations during the voyage.

(16) Workstation for safe operation means a workplace dedicated to the organization and control of onboard emergency and distress operations with easy access to external and internal communications and information relevant to the safe status of the ship.

(17) Workstation for communication means a workplace for the operation and control of Global Maritime Distress and Safety System (GMDSS) equipment and on-board communications for ship operation under normal and emergency conditions.
(18) Commanding field of vision means the field of view within which there is no obstacle to the ability of the on-duty navigator and pilot to perform their main tasks, and it is at least to provide the field of vision required by the safe performance of collision avoidance function. It is required that the sea field of vision from the front of the bow to 10° of either side of the ship is not to be obscured by more than two ship's lengths or 500 m, whichever is less, and that the horizontal view extends to a sector of at least 225°, that is, from dead ahead to either side of the ship is not less than 22.5° abaft the beam.
(19) Command position means a position located in the bridge, to monitor and guide the ship through the narrow water and buoy channel by visual observation, and provide the commanding field of vision, close field of vision of the sea surface and the information needed for maneuvering.
(20) Ship length means the length as defined in Reg.3.10, Chapter 1 of the International Regulation for Prevention Collision at Sea, 1972 , i.e. overall length of the ship.

4.1.4 Plans and documents

4.1.4.1 The following plans and documents are to be submitted for approval:
(1) Bridge visibility calculations, including scantlings of bridge, inclination and dimensions of windows and dimensions of consoles and so on;
(2) Arrangement of bridge, including positions of workstations, navigational equipment and consoles etc.;
(3) Arrangement of console panels;
(4) Diagram of power supply system for navigational equipment, internal communication equipment etc.;
(5) layout and power supply of cameras, where applicable.

Section 2 BRIDGE LAYOUT

4.2.1 General requirements

4.2.1.1 The bridge configuration, the arrangement of consoles and equipment locations is to enable the officer of the watch to perform navigational duties and other functions allocated to the bridge as well as maintain a proper lookout from a convenient position on the bridge.
4.2.1.2 A workstation for navigation manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions. All relevant instrumentation and controls are to be easily visible, audible and accessible from related workstations.
4.2.1.3 The bridge layout and design of workstations are to enable the ship to be navigated and manoeuvred safely by two navigators in cooperation.
4.2.1.4 External sound signals and fog signals from outside the ship that are audible on the open deck, are also to be audible inside the wheelhouse; a transmitting device is to be provided to reproduce such signals inside the wheelhouse (recommended frequency range: 70 Hz to 700 Hz).
4.2.1.5 A workstation for navigation manoeuvring is to be arranged on the starboard side near the center line, where applicable..
4.2.1.6 A workstation for monitoring is to be arranged on the port side near the center line, where applicable.
4.2.1.7 A Workstation for manual steering is to generally be located at the center line of the ship.
4.2.1.8 Sufficient manoeuvring positions are to be provided near the middle front window. If the view in the center line is obstructed by large masts, cranes, etc., two manoeuvring positions with a clear forward view are to be provided, one at the left side of the center line and the other at the right side, spaced not more than 5 m.

4.2.2 Field of vision

4.2.2.1 In order to obtain sufficient field of vision for safe navigation and manoeuvring of the ship, every effort is to be made to place the bridge above all other decked superstructures.
4.2.2.2 The view of the sea surface from the workstations for navigation manoeuvring is not to be obscured by more than two ship's lengths or 500 m, whichever is less, forward of the bow to 10º on either side, irrespective of the ship's draught, trim and deck cargo, as shown in Figure 4.2.2.2.

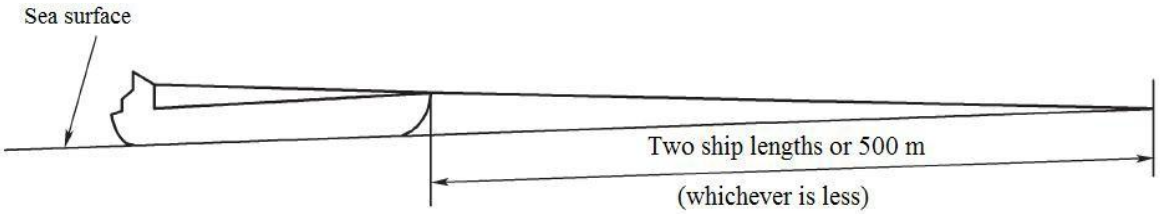


Figure 4.2.2.2 Forward View

4.2.2.3 No blind sector caused by cargo, cargo gear or other obstructions outside of the wheelhouse forward of the beam which obstructs the view of the sea surface as seen from the workstations for navigation manoeuvring is not to exceed 10º. The total arc of blind sectors is not to exceed 20º. The clear sectors between blind sectors are to be at least 5º. However, in the view described in 4.2.2.2, each individual blind sector is not to exceed 5º.

4.2.2.4 The horizontal field of vision from the workstations for navigation manoeuvring is to extend at least over an arc from 22.5º abaft the beam on one side, through forward, to 22.5º abaft the beam on the other side, as shown in Figure 4.2.2.4.

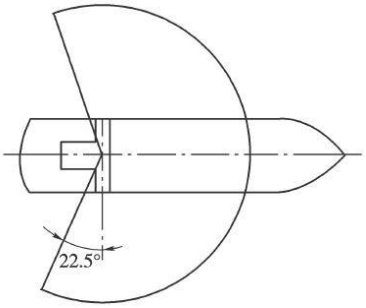


Figure 4.2.2.4 Field of Vision from the Workstations for Navigation Manoeuvring

4.2.2.5 The horizontal field of vision from the workstation for manual steering is to extend over an arc from right ahead to at least 60º on each side of the ship, as shown in Figure 4.2.2.5.

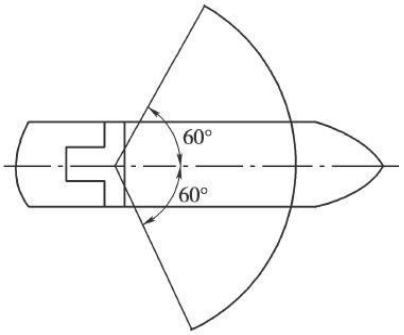


Figure 4.2.2.5 Horizontal Field of Vision from the Workstation for Manual Steering

4.2.2.6 The horizontal field of vision from workstation for docking is to extend over an arc from 45º on the opposite bow through dead ahead and then aft to 180º from dead ahead, as shown in Figure 4.2.2.6.

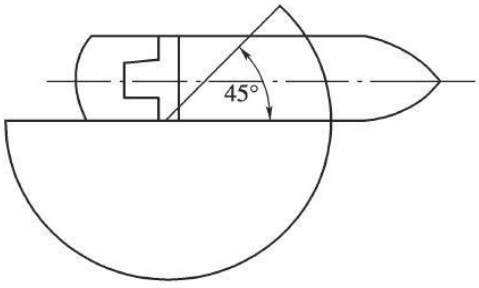


Figure 4.2.2.6 Horizontal Field of Vision From the Workstation for Docking

4.2.2.7 At a workstation for monitoring, the field of vision is to enable the officer of the watch to maintain a proper lookout. The field of vision is to extend at least over an arc from 90º on port bow, through forward, to 22.5º abaft the beam on starboard, as shown in Figure 4.2.2.7.

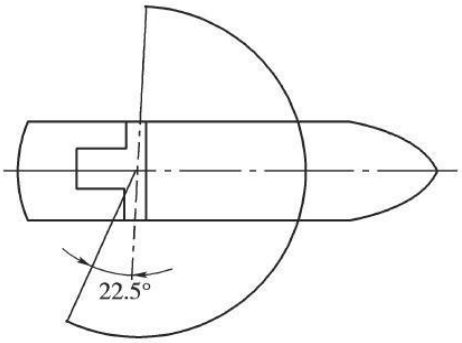


Figure 4.2.2.7 Field of Vision form Workstations for Monitoring

4.2.2.8 The ship's side is to be visible from the bridge wing.①

4.2.3 Windows

4.2.3.1 All windows in the wheelhouse are to be of shatter-proof reinforced glass, the thickness of which is to comply with acceptable standards②. Polarized and stained glass windows are not to be installed.

4.2.3.2 Windows are to be as wide as possible. Framing between windows is to be kept to a minimum and not installed immediately forward of any workstation.

4.2.3.3 To help avoid reflections, the bridge front windows are to be inclined as possible from the vertical plane top out, at an angle of not less than 10º and not more than 25º. Alternative means are to be approved by ISC.

4.2.3.4 The height of the lower edge of front windows is to allow a forward view above the bow from the workstation for navigation manoeuvring. To achieve this, the height of the lower edge above the deck is not to exceed 1 m as practicable.

4.2.3.5 The upper edge of the navigation bridge front windows are to allow a forward view of the horizon, for a person with a height of eye of 1.8 m above the bridge deck at the conning position, when the ship is pitching in heavy seas. If deemed that a height of eye of 1.8 m is unreasonable and impractical, reduction of the height of eye may be allowed, but not to less than 1.6 m.

4.2.3.6 At all times, regardless of weather conditions, at least two windows in front of the workstations for navigation manoeuvring, monitoring and docking (if practical) are to provide a clear view.

4.2.3.7 To ensure a clear view in bright sunshine, sunscreens of roller blind type with minimum colour distortion are to be affixed to windows that are within the required field of vision from the workstations. Such screens are to be readily removable and not to be permanently fixed.

4.2.3.8 At least two windows in front of the workstations for navigation manoeuvring, monitoring and docking (where applicable) are to be provided with efficient cleaning, de-icing and de-misting systems to ensure a clear view under all operating conditions.

4.2.3.9 A safe external passageway or similar arrangement is to be provided under the bridge front window to enable cleaning in the event of failure of the systems specified in 4.2.3.8 of this Section.

4.2.4 Layout and dimensions

4.2.4.1 The design of the net height of the wheelhouse ceiling is to take into account the overhead mounted panels and equipment. There is to be at least 2.25 m between the wheelhouse deck and the ceiling beams. The lower edge of ceiling mounted equipment is to be at least 2.1 m above the deck of open areas, walkways and standing-type workstations.

4.2.4.2 Workstations are to be divided into two areas as far as possible:

(1) the vertical (tilted) part so that the display is in a position that is easy to read;

(2) the horizontal part (table top) so that the controller, switch and button are within easy reach of the working position.

---

① Refer to IMO MSC.1/Circ.1350/Rev.1.

② Refer to ISO 21005 Ships and marine technology − Thermally toughened safety glass panes for windows and sidescuttles.

4.2.4.3 The height of the console desktop of the workstation for navigation manoeuvring and the workstation for monitoring is to make it easy to use the equipment required for safe execution of the tasks performed from the standing and sitting positions.
4.2.4.4 The chart table is to be large enough to accommodate all nautical chart sizes in common use internationally, and appropriate lighting is to be provided.
4.2.4.5 Instruments and equipment operated by the navigator at the workstation for navigation manoeuvring are to be within reach of the manoeuvring.
4.2.4.6 Instruments, indicators and displays providing information considered essential for the safe and efficient performance of tasks at the workstation for navigation manoeuvring are to be easily readable from this workstation.

4.2.5 Passageways

4.2.5.1 A passageway through the wheelhouse from bridge wing to bridge wing is to be provided. The width of the passageway is to be at least 1200 mm, but if there are obstacles on the route of the passageway, the width of the passageway at the obstacle can be reduced to 700 mm without affecting the staggered passage of two wheelhouse personnel.
4.2.5.2 The distance between adjacent workstations is to be sufficient to allow the unimpeded passage of persons not working at the station. The passage space of the corridor between different workstation areas is to be at least 700 mm. The workstation operation area is to be a part of the workstation, not a passageway.

4.2.6 Doors

4.2.6.1 Doors to the bridge are to be capable of being secured from inside and manually operated. Doors to the bridge wings are not to be self-closing and means are to be made to keep them open.

Section 3 WORKING ENVIRONMENT

4.3.1 Lighting

4.3.1.1 An adequate level of lighting facilitating the performance of all bridge tasks at daytime and nighttime is to be provided. With illumination inside the equipment or the lighting system in the wheelhouse, controls, indicators, instruments, keyboard etc. are to be clearly visible.
4.3.1.2 All lighting of instruments, keyboards and controls are to be adjustable down to zero, except the lighting of alarm indicators and the control of dimmers, which are to remain readable.
4.3.1.3 The lighting on the bridge is to be supplied by two exclusive circuits, with one of which fed from an emergency source of electrical power, in such a way that failure of any one of the circuits does not leave the bridge in darkness.
4.3.1.4 The lighting on the bridge is to be designed so as not to impair the night vision of the officer on watch. Lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision adaptation is not impaired, e.g. red lighting. Such lighting is to be arranged so that it cannot be mistaken for a navigation light by another ship. It is to be noted that red lighting is not to be fitted over the chart table so that possible confusion in colour discrimination is avoided.
4.3.1.5 High contrast between the brightness of the working area and the surrounding environment is to be avoided, that is, the brightness of the working area is not to be greater than 3 times the average brightness of the surrounding area.
4.3.1.6 Lighting sources are to be designed and positioned to avoid glare on working and display surfaces. The light sources are not to produce a detectable flicker.

4.3.2 Personnel safety precautions

4.3.2.1 The bridge area is to be free of physical hazards to bridge personnel. There are to be no sharp edges or protuberances which could cause injury to personnel. The wheelhouse, bridge wings and bridge deck are to be free of trip hazards and to have a non-slip surface whether it is wet or dry.
4.3.2.2 Sufficient hand-rails or equivalent thereto are to be fitted in the wheelhouse and around workstations to enable personnel to move or stand safely in bad weather. Special consideration is to be given to the protection of stairway openings.
4.3.2.3 For seating in the wheelhouse, means for securing are to be provided.
4.3.2.4 All safety equipment on the bridge is to be clearly identified and easily accessible and its storage location is to be clearly indicated.

4.3.3 Temperature and humidity

4.3.3.1 According to climate, adequate air-conditioning or mechanical ventilation system and efficient heating system are to be provided to maintain the temperature in the wheelhouse within the range of 14℃~ 30℃. The controls of these systems are to be fitted in the wheelhouse.
4.3.3.2 Air flow from air conditioning and heating systems to the workplace is to be avoided.

4.3.4 Noise
4.3.4.1 The noise level on the bridge is not to interfere with verbal communication, mask audible alarms or be uncomfortable to bridge personnel. The noise level in the wheelhouse is not to exceed 65 dB(A) in good weather. However, the noise level in the communication workstation) is not to exceed 60dB(A).

4.3.5 Vibration
4.3.5.1 The vibration level on the bridge is not to be uncomfortable to the bridge personnel.

4.3.6 Glare-free
4.3.6.1 A glare-free coating is to be applied on the front surface of bulkheads, deckhead, consoles, chart table and other essential equipment. Means are to be provided to prevent dimming of the information shown by visual displays and instruments covered by transparent sheeting.

Section 4 WORKSTATIONS

4.4.1 General requirements
4.4.1.1 According to its functions, the ship bridge can be divided into workstation for navigation manoeuvring, workstation for monitoring, workstation for manual steering, workstation for planning development, workstation for communication, workstation for docking and workstation for safe operation.
4.4.1.2 The workstation for navigation manoeuvring, workstation for monitoring and workstation for manual steering are functionally related and generally close to each other, so there is no need to re-equip these stations with relevant equipment.

4.4.2 Workstation for navigation manoeuvring
4.4.2.1 The workstation for navigation manoeuvring is generally to be provided with the following equipment:
(1) radar / ARPA;
(2) display of positioning system;
(3) depth indicator;
(4) speed and distance indicator;
(5) display of gyro compass system;
(6) wind direction and speed indicator;
(7) indicator of steering gear and rudder angle;
(8) rate-of-turn indicator;
(9) course and track monitoring system;
(10) controls and indicators for main and athwartship propulsion;
(11) verification device and manually activating device used for bridge navigation watch alarm system (BNWAS);
(12) an internal communication system (see 4.5.5);
(13) VHF radiotelephone installation;
(14) clock;
(15) window wipe and wash control device;
(16) navigation light control;
(17) whistle control device;
(18) Morse lamp key;
(19) lighting control of wheelhouse and equipment;
(20) display for the Automatic Identification System (AIS)；
(21) a device that stops sending Long-Range Identification and Tracking (LRIT) messages, if applicable;
(22) Electronic Chart Display and Information System (ECDIS);
(23) night vision equipment, if applicable.
4.4.2.2 The ship is to be provided with two separate and independent radar systems. At least one of the radars is to operate within the X-band. The radars are to be capable of detecting and clearly indicating any

input signal loss (e.g. video or azimuth signal). The ship is also to be equipped with an ARPA system which may be independent or built into the radar equipment.
4.4.2.3 At least two positioning systems capable of continuously displaying latitude and longitude are to be fitted, one of which is to be electronic positioning system with global coverage and the other is to be electronic positioning system with differential correction function.
4.4.2.4 An off-course alarm independent of automatic steering system is to be provided. Where an automatic track-keeping system is provided, an off-course alarm may be initiated by the positioning system in case of deviation from the planned route to the set distance.
4.4.2.5 Where an automatic track-keeping system is provided, a pre-warning is to be given at the approach of a way-point so that the back-up navigator will have sufficient time to reach the wheelhouse for acknowledging course alteration in case of any officer of the watch deficiency. The course is not to be automatically altered without prior confirmation.

4.4.3 Workstation for monitoring

4.4.3.1 The workstation for monitoring is generally to be provided with the following equipment:
(1) radar /ARPA;
(2) the display of the depth sounder;
(3) speed and log display;
(4) compass display;
(5) steering gear and rudder angle indicator;
(6) rotation rate indicator;
(7) controllers and indicators for main propulsion and side push;
(8) BNWAS confirmation device and manual starting device;
(9) Internal communication system (see 4.5.5);
(10) VHF radio telephone;
(11) time indicator;
(12) window cleaning controller;
(13) air whistle controller.

4.4.4 Workstation for manual steering

4.4.4.1 The workstation for manual steering is generally to be provided with the following equipment:
(1) steering wheel/helmsman's handle;
(2) steering gear selection switch;
(3) compass display;
(4) steering gear and rudder angle indicator;
(5) rotation rate indicator.

4.4.5 Workstation for plan development

4.4.5.1 The workstation for plan development is to enable the following tasks to be performed:
(1) determining the ship’s position;
(2) planning the forthcoming voyage and estimating time of arrival at various way-points;
(3) indicating time.
4.4.5.2 The time indication at the workstation for plan development is to be derived from the same system as the workstation for navigation manoeuvring.

Section 5 EQUIPMENT AND SYSTEMS

4.5.1 Basic requirements for equipment

4.5.1.1 Navigation equipment is to be subject to type approval and the performance standards are not to be inferior to those of IMO in force.
4.5.1.2 All instruments and panels are to be permanently mounted in consoles or at other appropriate places, taking into account both operational and environmental conditions.
4.5.1.3 When siting equipment which is to be used in an exposed position, special care is to be taken to ensure that the siting does not impair the performance of the equipment.
4.5.1.4 Antenna and sensor arrangements which are part of navigational instruments, are to be widely separated from radio communications systems.
4.5.1.5 Antenna units are to be sited so as not to constitute a hazard to personnel working in the vicinity.

4.5.1.6 Satcom and radar antenna units are required to have a warning label, detailing safe distances, posted in the vicinity or on the equipment.
4.5.1.7 Above-deck equipment is to be sited so as to prevent the installation from being affected by vibration.
4.5.1.8 Instruments to be installed are to be located away from excessive heat sources, such as a heating vent or equipment heat exhaust.
4.5.1.9 Instruments to be fitted into a bridge instrument console are to be protected from excessive heat by conduction or, if necessary, by forced air flow.
4.5.1.10 Equipment not specifically designed for outdoor installation is not to be installed near a doorway, open window or hatch opening.
4.5.1.11 When equipment is being installed, care is to be taken to ensure that the accuracy of the ship's magnetic compasses is adequately safeguarded.

4.5.2 Computer-based systems and software
4.5.2.1 Computer-based systems are subject to type approval, and are to comply with the applicable requirements of Section 6, Chapter 2, PART SEVEN of the Rules.
4.5.2.2 Where failure in computer-based systems may affect safe navigation and manoeuvring of the ship, back-up systems are to be available for changeover.
4.5.2.3 Adequate filtering of analogue and digital input signals is to be provided.
4.5.2.4 Software and data necessary to ensure satisfactory performance of the computer system are to be stored in a non-volatile memory, or a volatile memory with an uninterruptible power supply.
4.5.2.5 Access to the computer's operating system is to be restricted, and any alteration of system software after final inspection and testing on board is to be subject to prior approval by ISC.
4.5.2.6 Necessary quality attributes for software are reliability, safeguard against error and misuse, fault detection and correction.
4.5.2.7 Where computerized equipment are interconnected through a computer network, failure of the network is not to prevent individual equipment from performing their individual functions.

4.5.3 Alarm system
4.5.3.1 Alarms released by navigation equipment are to be both audible and visual and to be displayed as group alarm for easy identification.
4.5.3.2 Alarms are to be set for the following as a minimum:
(1) the closest point of approach;
(2) insufficient depth of water;
(3) approach of a way-point;
(4) yaw;
(5) off-track;
(6) steering gear failure;
(7) navigation light failure;
(8) gyrocompass failure.

4.5.4 BNWS
4.5.4.1 The wheelhouse is to be provided with a BNWAS, the performance of which is to comply with the requirements of IMO resolution MSC.128(75).

4.5.5 Communication
4.5.5.1 A telephone system is to be provided for two-way speech communication between the bridge and at least the following (the telephone system is to function properly in case of loss of main power supply):
(1) engine control station;
(2) emergency steering position in steering gear room;
(3) cabins of captain and officers, offices, mess and public areas.
4.5.5.2 The bridge is to have priority over the communication system.
4.5.5.3 All extension numbers are to be shown at any telephone.

4.5.6 Power supply
4.5.6.1 Local distribution panels are to be arranged for all items of electrically operated navigational equipment etc. These panels are to be supplied by two exclusive circuits, one fed from the main source of electrical power and the other fed from an emergency source of electrical power. Each item of navigational equipment is to be individually connected to its distribution panel. The power supplies to the distribution

panels are to be arranged with automatic changeover facilities between the two sources. Failure of any power source is to initiate an audible and visual alarm.
4.5.6.2 Following a loss of power which has lasted for 45s or less, all primary functions are to be readily reinstated. Following a loss of power which has lasted for more than 45s, as many as practical primary functions are to be readily reinstated.

4.5.7 Man-machine interface

4.5.7.1 All instruments are to be logically grouped according to their functions within each workstation. Their location and design are to give consideration to the physical capabilities of the human operator and comply with accepted ergonomic principles.
4.5.7.2 The amount of information to be presented for conducting various tasks as well as the methods of displaying the information needed are to give consideration to the capabilities of the human operator to percept and process the information made available.
4.5.7.3 Instruments or displays providing visual information to more than one person are to be located for easy viewing by all users concurrently. If this is not possible, the instruments or displays are to be duplicated.
4.5.7.4 The method of presentation is to ensure that the instrument data is clearly visible to the observer at a practicable distance in the light conditions normally experienced on the bridge by day and by night.
4.5.7.5 Means are to be provided for the manual adjustment of the brightness of each visual display unit.
4.5.7.6 All information is to be presented on a background of high contrast, emitting as little light as possible by night.
4.5.7.7 Paged displays are to be presented in a way which allows the operator to find quickly the information needed. An overview page is to be easily available to remind the operator of the paging system.
4.5.7.8 Each page is to have a unique identifying label on the screen.
4.5.7.9 The function and layout of control elements are to be logically coordinated.
4.5.7.10 Maloperation of a computer-based bridge instrument is not to cause any loss of data, damage of programmes or malfunction of the system.
4.5.7.11 Default values, where applicable, are to be indicated by the system when requesting operator input.
4.5.7.12 If an input error is detected by the system, the operator is to be allowed to correct the error immediately.
4.5.7.13 The system is to require confirmation from the operator for critical actions, e.g. they are not to rely on single keystrokes.

Section 6 SUPPLEMENTARY REQUIREMENTS FOR THE NOTATION BDE-2

4.6.1 General requirements

4.6.1.1 Ships applying for the notation BDE-2 are to comply with the requirements of this Section in addition to the applicable requirements of other sections of this Chapter.

4.6.2 Field of vision

4.6.2.1 It is to be possible to observe all objects of interest for the navigation, such as other traffic and navigation marks, in any direction from inside the wheelhouse. Bearing this in mind, the observer is to obtain a 360º field of vision from inside the wheelhouse when moving within a certain range there. For rear view, other measures of the equivalent level of safety are acceptable, such as cameras with redundancy covering any obstructing view or blind area, if the 360 ° field of vision requirement around the ship cannot be met.
4.6.2.2 At the workstation for navigation manoeuvring, in the horizontal plane to vertical 5° above the line of sight, there is to be no obstruction; any structure/equipment or cargo obstructing the sea surface near the vessel in excess of 1000 m within a 180º sector in front of the lateral vessel in a line of sight from the horizontal plane to 5° below vertical is to be considered a blind area and the necessary calculations is to be carried out (eye height 1800 mm).
4.6.2.3 In all draft, trim and deck cargo conditions, the wheelhouse from the commanding position is to be able to observe all objects, shoreline and water at least 500 m from the hull within a sector of 10º to 90° on each side of the bow. If the vessel cannot meet the above requirements, measures of the equivalent level of safety are acceptable, such as cameras with redundancy covering any obstructing view or blind area.

4.6.2.4 In the process of ship manoeuvring, the navigator at the workstation for docking is to be able to observe the parallel ship side (eye height: 1600 mm). The total length of visibility on the ship's side is not to be less than 1/2 of the ship length.

4.6.3 Windows

4.6.3.1 To prevent reflection, the rear and side windows are to be tilted outwards at an angle of not less than 5° at the top of the vertical plane. The window in the bridge wing door may be exempted from this requirement.

4.6.4 Layout and dimensions

4.6.4.1 To provide accessibility from a standing position, the height of the console table top above the wheelhouse deck surface is to be not higher than 800 mm and not lower than 750 mm. For easy operation of the control device from the sitting position, it is to be possible to adjust the sitting height so that the elbow height is 50 mm higher than the console table.

4.6.4.2 The console in front of the work seat is to provide sufficient legroom to facilitate access to the equipment and control equipment to be used.

4.6.4.3 The shape of the console and the position of the display are to be designed to provide the user with the information required to perform the primary functions of the workstation within a viewing angle of 95° per side from the front.

4.6.4.4 If the seat is installed in the station used for standing and sitting operation, the seat is to be attached to the slide rail so that the seat can move back and forth to make it easy to operate the equipment while sitting, and there is enough space to stand in front of the console when the seat is pushed back, generally 700 mm. It is to be possible to adjust the height of the seat to accommodate users of different heights to obtain the best view and to achieve the best range of sight. Armrests (if provided) are to be of folding type and adjustable in height. Seats are to be equipped with adjustable trestles.

4.6.5 Passageways

4.6.5.1 The height of the entrance and door from the adjacent passageway to the wheelhouse is not to be less than 2.0 m.

4.6.5.2 At the workstation for docking, the distance between the bridge wing bulwarks, bulkheads and bridge wing consoles is to be as small as possible and the passageway is to be wide enough for one person to pass comfortably through the consoles. The width of the passageway is to be at least 600 mm.

4.6.6 Workstation for docking

4.6.6.1 The workstation for docking is to be capable of ship manoeuvring and is generally to be provided with the folloing equipment:

(1) compass display;
(2) wind speed and direction indicator;
(3) steering gear and rudder angle indicator;
(4) rotation rate indicator;
(5) controllers and indicators for main and side propulsion;
(6) BNWAS confirmation device and manual starting device;
(7) internal communication system.

Section 7 INTEGRATED BRIDGE SYSTEM (IBS)

4.7.1 General requirements

4.7.1.1 This Section applies to ships fitted with an IBS.

4.7.1.2 The layout of the IBS is to be such that the failure of one sub-system is immediately brought to the attention of the officer of the watch through auditory and visual alarms, and will not lead to the failure of any other sub-systems. If one part of an integrated navigation system (INS) fails, every other piece of equipment or every other part of the system is to be able to operate separately.

4.7.1.3 The performance criteria of the IBS is to comply with the requirements of IMO SN.1/Circ.288 Guidelines for Bridge Equipment and Systems, their Arrangement and Integration.

4.7.1.4 Ships applying for the notation BDE-3 are to comply with the requirements of this Section in addition to the applicable requirements of other sections of this Chapter.

4.7.2 Equipment

4.7.2.1 Two gyrocompasses capable of continuously displaying heading information and providing navigation equipment with corresponding input information are to be installed.
4.7.2.2 Only one gyrocompass is to be used at any time for main display and control purposes. The navigating officer is to be able to switch between compasses at any time and the non-selected compass is to be used automatically as the independent heading source for the off-course warning.
4.7.2.3 It is to be possible to compare readings from each gyrocompass via the navigation workstation displays. Automatic comparison between the compasses is to be provided and an alarm given, should the difference between heading signals exceed a pre-set value.

4.7.3 Alerts and management thereof

4.7.3.1 Navigation and operation workstations are to have a Bridge Alert Management (BAM) system that meets the requirements of IMO resolution MSC.302(87).
4.7.3.2 The BAM system is to provide the following alerts as a minimum:
(1) deviation from the route;
(2) close to the waypoint;
(3) incorrect or lost position;
(4) loss of heading input;
(5) equipment or sub-system failure;
(6) incompatibility of the compass.
4.7.3.3 Alerts are to be prioritized according to the type of emergency and response required by the navigation and operating workstations.
4.7.3.4 Within each priority, alerts will be arranged in groups to reduce the amount of information provided to the operator. However, the following alerts cannot be grouped:
(1) emergency alarm.
(2) a separate set of alarms related to a failure requiring reduction of speed or power or automatic shutdown of propulsion machinery.
(3) steering gear alarm.
(4) navigation light fault alarm.
4.7.3.5 The alerts are to be presented grouped in order of priority. Within the priorities the alerts are to be displayed in the order in which they occur (sequence). The visual display unit will provide an immediate display of new information, regardless of the currently selected information display.
4.7.3.6 Unacknowledged alerts can be distinguished by flashing text or by flashing markers adjacent to the text, not just by color changes. Acknowledged alerts can be distinguished by steady illuminated text or steady illuminated markers adjacent to the text.

CHAPTER 5 ADDITIONAL REQUIREMENTS FOR FISHING VESSELS

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 The provisions of this Chapter apply to fishing vessels.

5.1.1.2 Fishing vessels complying with the Rules for Construction of Ocean-going Steel Fishing Vessels are to be assigned the Fishing Vessel class notation.

5.1.1.3 Unless expressly provided by this Chapter, fishing vessels are to comply with the relevant requirements of PART ONE of the Rules.

5.1.2 Definitions

5.1.2.1 The definitions of this Chapter are as the following:

(1) Length L_L: refers to 96% of the total length of the waterline at 85% of the minimum moulded depth on the upper edge of the keel plate, or the length along the waterline from the leading edge of the bow to the center of the rudder stock, whichever is greater. For fishing vessels without rudder stock, the length L_L is taken as 96% of the total length of the waterline at 85% of the smallest depth. If the shape of the bow above the waterline at the minimum depth of 85% is concave, the foremost end of the total length and the front edge of the bow shall be measured from the point where the last point of the shape of the bow above the waterline is projected vertically on the waterline (see figure 5.1.2.1-1).For fishing vessels whose keel is designed to be inclined, the waterline for measuring this length should be parallel to the design waterline at 85% of the minimum moulded depth D_{min}. The waterline is obtained by drawing a tangent line parallel to the keel line of the fishing vessel and tangent to the depth arc of the working deck in the figure below. In this case, the minimum depth is the vertical distance measured from the upper edge of the keel plate to the upper side of the beam at the side of the working deck at the tangent point (see figure 5.1.2.1-2).

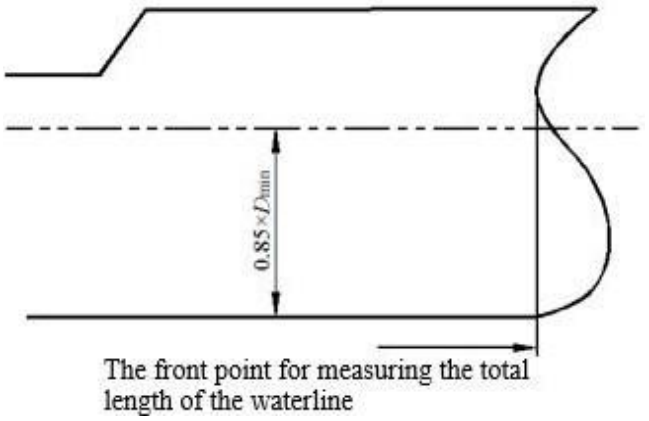


Figure 5.1.2.1-1 The front point for measuring the total length of the waterline, for fishing vessels with recessed bow shape.

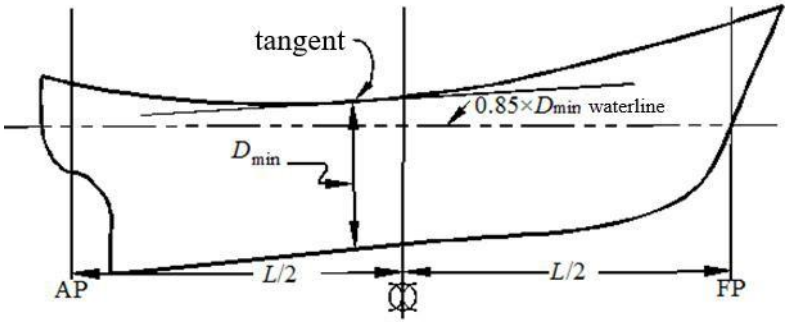


Figure 5.1.2.1-2 The length of a leaning keel fishing vessel

(2) Keel line: refers to the line that passes through the following specific points in the vessel and is parallel to the slope of the keel: for metal hull fishing vessels, it is the line of the upper edge of the keel or the line of intersection between the inner edge of the hull plate and the keel; if there is a bar keel, then it is the intersection point between the bar keel extension line and the inner side of the hull plate. For non-metallic fishing vessels, it is the intersection of the respective extension lines of the outer surface of the bottom and the outer surface of the bar keel; if there is no bar keel, it is the bottom point.
(3) Breadth B: refers to the maximum width in a fishing vessel. For a metal shell, the breadth is measured at the midship to the inner surface of the hull; for a fishing vessel with other material shells, the breadth is measured at the midship to the outer surface of the hull.
(4) Depth D: the vertical distance measured from the upper edge of the keel plate to the upper edge of the beam at the side of the working deck. For fishing vessels with wooden and mixed material structures, the vertical distance is measured from the lower edge of the keel notch. If the shape of the lower part of the midship section is concave, or when thickened keel wing panels are installed, the vertical distance is measured from the point where the inward extension line of the flat part of the bottom of the ship intersects with the side of the keel. If the working deck is stepped and its raised part extends beyond the point that determines the moulded depth, the moulded depth shall be measured to the extended dashed line of the lower part of the deck, which is parallel to the raised part of the deck. If there are no special regulations, it generally refers to the depth of the middle of the ship.
(5) Working deck: is generally the lowest complete deck above the deepest operating waterline from which fishing is undertaken. In vessels fitted with two or more complete decks, the lower deck as a working deck provided that the deck is situated above the deepest operating waterline.
Where the lowest complete deck above the deepest operating waterline is stepped, the lowest line of the deck and the continuation of that line parallel to the upper part of the deck is taken as the working deck.
Discontinuous working deck, stepped working deck,

① Where a recess in the working deck does not extend to the sides of the ship, the upper part of the deck is taken as the working deck (see figure 5.1.2.1-3).
② Recesses not extending from side to side in a deck below the exposed deck, designated as the working deck, may be disregarded, provided all openings in the weather deck are fitted with weathertight closing appliances.
③ Recesses not extending from side to side in a deck below the exposed deck, designated as the working deck, may be disregarded, provided all openings in the weather deck are fitted with weathertight closing appliances.

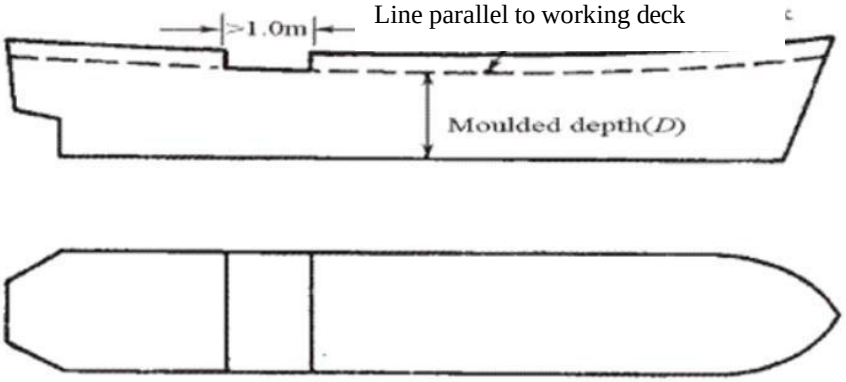


Figure 5.1.2.1-3 the working deck of a recess

Section 2 SURVEYS DURING CONSTRUCTION

5.2.1 Requirements for surveys and tests of fishing vessels

5.2.1.1 Unless expressly provided by this Section, surveys and tests of fishing vessels are to comply with the provisions of Sections 1 and 2, Chapter 4, PART ONE of the Rules.
5.2.1.2 Unless expressly provided by the flag State, the list of certification for statutory products of fishing vessels is to comply with the relevant requirements of Chapter 3 , PART ONE of the Rules.

5.2.1.3 Tests of fishing vessels are to comply with the requirements of 4.2.3, Section 2, Chapter 4, PART ONE of the Rules, except that 4.2.3.3(3) is not applicable. The tightness tests of compartments are to comply with the requirements of Part B, Annex 1, Section 3, Chapter 4, PART ONE of the Rules.
5.2.1.4 For hull surveys carried out in accordance with Appendix 1, Chapter 4, PART ONE of the Rules, statutory requirements of relevant SOLAS regulations corresponding to tightness test and structural test in Table 1 of this Appendix may not apply. Statutory requirements of SOLAS or ILLC '66 corresponding to other shipbuilding function in Table 1 are to be replaced by relevant requirements of the Administration of the flag State.
Annex 2 of Appendix 1, Chapter 4, PART ONE of the Rules is not applicable to fishing vessels.
5.2.1.5 Unless expressly provided, Appendix 2 , Chapter 4 , PART ONE of the Rules is not applicable to fishing vessels.
5.2.1.6 At surveys during construction of fishing vessels, survey items are at least to include:
(1) inspecting the hull structure of fish hold to ensure that the materials, scantlings, construction, arrangement and installation are in accordance with the approved plans, diagrams, specifications, calculations and other technical documentation and that the workmanship is in all respects satisfactory;
(2) confirming the validity of the fish hold polyurethane foam test report;
(3) confirming the availability of the alarm system fitted in the refrigerated room and fish hold.

Section 3 SURVEYS AFTER CONSTRUCTION

5.3.1 General requirements

5.3.1.1 For the purpose of maintaining the validity of certificates, fishing vessels which have been classed with ISC are to be subject to the surveys as specified in this Section.
5.3.1.2 Unless expressly provided by this Section, surveys after construction of fishing vessels are to comply with the provisions of Chapter 5, PART ONE of the Rules.
5.3.1.3 The following requirements in Chapter 5, PART ONE of the Rules are not applicable to surveys after construction of fishing vessels:
(1) provisions of Sections 3, 5, 6, 7, 8, 16, 17 and 18;
(2) Appendixes 2, 3, 6, 10, 11, 12, 13, 17, 18, 19 and 20.
5.3.1.4 At surveys after construction of fishing vessels, survey items are at least to include:
(1) inspecting the general conditions of fish hold;
(2) confirming the availability of the alarm system fitted in the refrigerated room and fish hold.

Section 4 INTACT STABILITY

5.4.1 General requirements

5.4.1.1 Compliance with the requirements for intact stability is a condition for classification of ships.
5.4.1.2 The intact stability of fishing vessels is to comply with the requirements of this Section, or it is to be demonstrated that their intact stability is in compliance with the requirements of the flag State Administration.
5.4.1.3 This Section applies to ocean-going fishing vessels of 24 m and over in length L_L.

5.4.2 Plans and documents

5.4.2.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Stability calculations for loading conditions or loading manual;
(2) Curves or table of allowable height of center of gravity or allowable initial metacentric height;
(3) Coordinates of opening of flooding angles and curves or table of flooding angles.
5.4.2.2 The following plans and documents are to be submitted for information:
(1) General arrangement;
(2) Lines and offsets;
(3) Hydrostatic curves or table;
(4) Stability cross curves or table;
(5) Capacity curves or table;
(6) Arrangement of bilge keels;
(7) Plan of load line marks and draught;
(8) Auxiliary calculations for windage area and moment of area, icing, etc.;
(9) Cross-sectional area (if applicable);

(10) Arrangement of fixed ballast (if applicable);
(11) Approved inclining test report or light ship survey report;
(12) Arrangement of portable fish-hold divisions (if applicable);
(13) Arrangement of fishing machinery (if applicable).
5.4.2.3 The above information may be reduced as appropriate for fishing vessels of which the intact stability has been approved.

5.4.3 Requirements for intact stability

5.4.3.1 The intact stability of fishing vessels is to comply with the relevant requirements of IMO resolution MSC.267(85) – International Code on Intact Stability, 2008 (2008 IS Code), Part B. For fishing vessels with B/D ≥ 2.5, the requirements of 2.2.3 of Part A of the Code may be substituted by the following criteria:
(1) The heeling angle corresponding to the maximum righting lever is not to be less than 15°;
(2) The area under the curve of righting levers is not be less than 0.07 m·rad up to an angle of 15° when the maximum righting lever occurs at 15º and 0.055 m·rad up to an angle of 30º when the maximum righting lever occurs at 30º or above. Where the maximum righting lever occurs at angles of between 15º and 30º, the corresponding area under the righting lever curve is to be:

$$0.055+0.001（30^\circ -\varphi_{max}）\ \mathrm{m \cdot rad}$$

where: φ_{max}——The heeling angle corresponding to the maximum righting lever（°）.
5.4.3.2 The angle of heel at which progressive flooding of fish-holds could occur through hatches which remain open during fishing operations and which cannot rapidly be closed shall be at least 20° unless the stability criteria of the righting lever curve of 5.4.3.1 can be satisfied with the respective fish-holds partially or completely flooded.
5.4.3.3 Vessels engaged in particular fishing methods where additional external forces are imposed on the vessel during fishing operations, shall take account of the effects of external forces on stability.
5.4.3.4 For special type fishing vessels such as beam trawler, net vessel, cage vessel etc, the special requirements (if applicable) of the Administration shall be satisfied.
5.4.3.5 For fishing vessels, the condition where ice accretion is likely to occur will have bad effects on the stability, so icing should be taken into account in the analysis of loading conditions. The following allowance shall be made in the icing calculations:
(1) 30kg/m^2 on exposed weather decks;
(2) 7.5kg/m^2 for projected lateral area of each side of the vessel above the water plane;
(3) the icing weight of the projected lateral area of rails, all kinds of booms, girder (except masts) and rigging, and the icing weight of the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.
If there is a significant difference between the icing conditions and the above requirements, the icing standard may be 0.5 to 2 times the required; if the expected icing exceeds 2 times the above-mentioned requirement, more stringent requirements can be adopted.

Section 5 DAMAGE STABILITY

5.5.1 General requirements

5.5.1.1 Compliance with the applicable requirements for damage stability is a condition for classification of vessels.
5.5.1.2 The damage stability of vessels is to comply with the requirements of this Section, or it is to be demonstrated that their damage stability is in compliance with the requirements of the flag State Administration.
5.5.1.3 Vessels of 100 m in length and over and the total number of persons carried is 100 or more should be checked for damage stability according to the requirements of this section.

5.5.2 Plans and documents

5.5.2.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Calculations of damage stability;
(2) Damage control plan.
5.5.2.2 The following plans and documents are to be submitted for information:

(1) General arrangement of doors and windows;
(2) General arrangement of scuttles, ventilators and air pipes;
(3) Plans and documents stated in 5.4.2 of this Chapter.

5.5.3 Requirements for damage stability

5.5.3.1 The damage stability of vessels is to comply with the relevant requirements of Regulation 14, Chapter III of the 1993 Torremolinos Protocol Relating to the 1977 Torremolinos International Convention for the Safety of Fishing Vessels as amended by the Cape Town Agreement of 2012 (hereinafter referred to as Convention for the Safety of Fishing Vessels).

Section 6 LOAD LINE MARKS AND MARKING

5.6.1 Load line marks

5.6.1.1 The load line marks and marking for ocean-going fishing vessels are to comply with the provisions of Section 11, Part 2 of this Rule.

5.6.1.2 If the load lines of certain seasons are not applicable due to the particularity of the fishing vessel or the nature of the business or restricted by navigation, these load line segments may not be mapped.

Section 7 STRUCTURAL ARRANGEMENT

5.7.1 General Provisions

5.7.1.1 The provisions of this section apply to ocean-going steel fishing vessels of 24 m and over in length.

5.7.2 **Arrangement of watertight bulkheads**

5.7.2.1 Fishing vessels shall be fitted with a collision bulkhead and at least watertight bulkhead in the before and after end of the main machinery space. Such watertight bulkheads shall be extended up to the working deck.

5.7.2.2 Watertight subdivision bulkhead whether transverse or longitudinal shall be prevented ingress of water from any direction in the water pressure produced in intact and damage condition. In all cases, watertight subdivision bulkheads shall be capable of supporting at least the pressure due to a head of water up to the working deck. In damage condition, water pressure shall be taken into account in the balance, including the worst condition of intermediate stage of flooding.

5.7.2.3 Steps and recesses in watertight bulkheads shall be as strong as the bulkhead at the place where each occurs.

5.7.3 **Arrangement of collision bulkheads**

5.7.3.1 The distance between collision bulkheads and forward perpendicular of fishing vessels shall be meets the following requirements:

(1) not less than 0.05L and not more than 0.08L for vessels of 45m in length and over;

(2) not less than 0.05L and not more than 0.05L plus 1.35m for vessels of less than 45m and more than 24m in length, expect as may be allowed by ISC;

(3) less than 2.0m for vessels of 24m in length and over.

5.7.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g., a bulbous bow, the distances specified in paragraph 5.7.3.1 of this Section shall be measured from a point at mid-length of the extension forward of the forward perpendicular or from a point 0.015L forward perpendicular, whichever is lesser.

5.7.3.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in paragraph 5.7.3.1 of this Section.

5.7.3.4 Where a long forward superstructure is fitted, the collision bulkhead shall be extended weathertight to the deck next above the working deck. The extension and collision bulkhead can be fitted on the different cross section provided it is located within the limits given in paragraph 5.7.3.1 of this Section and the part of the deck which forms the step is made effectively weathertight.

5.7.3.5 The pipes piercing the collision bulkhead shall be fitted with stop values capable of being operated from above the working deck, the valve being located inside the forepeak at the collision bulkhead with a indicator being used for show that the value turn on or off. The fitting of the valve without

institution operated from above the working deck on the after side of the collision bulkhead shall be authorized, provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space. All valves shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

5.7.3.6 No doors, manholes, access openings, or any other openings shall be fitted in the collision bulkhead below the working deck The number of openings in the collision bulkhead above the working deck shall be restricted to the minimum compatible with the design and normal operation of the vessels. All such openings shall be capable of being closed weathertight.

5.7.4 Stern tubes

5.7.4.1 In all cases stern tubes shall be enclosed in watertight spaces of moderate volume, to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements.

5.7.5 Openings and their closing appliances

5.7.5.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the fishing vessels. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

5.7.5.2 The acceptability height of hatchways coamings and sills for openings are to comply with the requirements in Table 5.7.5.2:

The acceptability height of hatchways coamings and sills for openings Table 5.7.5.2

Item \ Opening position	Position 1	Position 2
Superstructure and deckhouse sill (mm)	380	300/150
Sill of companionways (mm)	380	300/150
Machinery space opening (mm)	600	300
Height of hatch coamings (mm)	600	450/300

5.7.5.3 Weathertight doors

(1) all access openings in bulkheads of enclosed superstructure and other outer structures through which water could enter and endanger the vessel, shall be fitted with doors permanently attached to the bulkhead, framed and stiffened so that the whole structure is of equivalent strength to the unpierced structure, and weathertight when closed. As an alternative measure, where the stairway in deckhouse could be enclosed in substantially constructed companionways fitted with weathertight door, the outer door need not to be weathertight. The means for securing these doors weathertight shall consist of gaskets and clamping devices or other equivalent means and shall be permanently attached to the bulkhead or to the doors themselves, and shall be so arranged that they can be operated from each side of the bulkhead;

(2) weathertight doors directly access to exposed space are to open outwards.

5.7.5.4 Fish-holds and other hatchways, miscellaneous openings in working deck and superstructure decks are to comply with the following requirements:

(1) the hatchways coamings are to have substantially constructed according to its positions. Where operating experience has shown justification, the height of these coamings may be reduced, or the coamings omitted entirely, provided that the safety of vessels is not thereby impaired. In this case, the hatchway openings shall be kept as small as practicable and the covers be permanently attached by hinges or equivalent means and be capable of being rapidly closed and battened down;

(2) the structure of hatchways closed by wood covers in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 15 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the *International Convention on Load Lines, 1966*;

(3) the structure of hatchways closed by covers other than wood in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 6 of Chapter II of *Convention for the Safety of Fishing Vessels*.

5.7.5.5 Machinery space openings are to comply with the following requirements:

(1) machinery space openings are to be appropriate framed and efficiently enclosed by steel casings. Where machinery casings are not protected by other structures，the strength shall be considered specially. Access openings in such casings are to be fitted with weathertight doors, the sills of which are not less than 600 mm. Where machinery casings are not protected by other structures, double watertight doors are to be required for ships assigned freeboards less than those based on relevant requirements. An inner sill is not

less than 230mm in conjunction with the outer sill of 600 mm; The non-return valve which is to be closed directly and controlled locally shall be provided for sea inlet and discharge of the enclosure space between the double doors;

(2) opening shall be fitted with hatchway covers permanently attached to the bulkhead, framed and stiffened so that the whole structure is of equivalent strength to the unpierced structure, and weathertight when closed except access opening.

5.7.5.6 Other deck openings are to comply with the following requirements:

(1) where it is essential for fishing operations, flush deck scuttles of the screw, bayonet or equivalent type and manholes may be fitted provided these are capable of being closed watertight and such devices shall be permanently attached to the adjacent structure, except secured by closely spaced bolts. Having regard to the size and disposition of the openings and the design of the closing devices, metal-to-metal closures may be fitted that they are effectively watertight;

(2) openings other than hatchways, machinery space openings, manholes and flush scuttles in the working or superstructure deck shall be protected by enclosed structures fitted with weathertight doors or their equivalent. Companionways shall be situated as close as practicable to the centerline of the vessels.

5.7.5.7 Ventilators are to comply with the following requirements:

(1) ventilators to spaces below working deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. For vessels of 45m in length and over, the height above deck of ventilators coamings shall be at least 900mm on the working deck and at least 760mm on the superstructures deck. For vessels of less than 45m in length, the height of these coamings shall be 760mm and 450mm respectively;

(2) coamings of ventilators shall be of equivalent strength to the adjacent structure and capable of being closed weathertight by closing appliances permanently attached to the ventilators or adjacent structure. The closing appliances shall be permanently attached to the ventilators; Where other vessels such not fitted as this，the closing appliances shall be stored near the specified ventilators and convenient for use. Where the coaming of any ventilators exceeds 900mm in height, it shall be specially supported.

The thickness of ventilator coamings shall be not less than the requirements in Table 5.7.5.7, but need not exceed that of the deck.

Thickness of Ventilator Coamings **Table 5.7.5.7**

Internal diameter of coaming (mm)	Thickness of coaming (mm)	Internal diameter of coaming (mm)	Thickness of coaming (mm)
≤200	7.5	350	9.0
250	8.0	400	9.5
300	8.5	≥450	10.0

(3) the coamings of ventilators extend to more than 4.5 m above the working deck, and the coamings of ventilators extend to more than 2.3 m above the superstructures deck, need not be fitted with closing arrangements for vessels of 45m in length and over. The coamings of Ventilators extend to more than 3.4 m above the working deck, and the coamings of Ventilators extend to more than 1.7 m above the superstructures deck, need not be fitted with closing arrangements for vessels of less than 45m in length;

(4) Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the working deck.

5.7.5.8 Air pipes are to comply with the following requirements:

(1) where air pipes to tanks and void spaces below deck extend above the working or the superstructure decks, the exposed parts of the pipes shall be of strength equivalent to the adjacent structures and fitted with appropriate protection. Openings of air pipes shall be provided with means of closing, permanently attaches to the pipe or adjacent structure.

The minimum wall thickness of air pipes above weather deck is to be:

6.0 mm for pipes of 80 mm external diameter or smaller;

8.5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation;

(2) the height of air pipes above deck to the point where water may have access below shall be at least 760mm on the working deck and at least 450mm on the superstructure deck.

5.7.5.9 Freeing ports are to comply with the following requirements:

(1) where bulwarks on weather parts of the working deck or superstructures deck form wells, sufficient measures shall be provided to discharge of shipped water rapidly and freed of water;

(2) freeing ports area of bulwarks are to comply with the requirements of Regulation 14 of Chapter II of *Convention for the Safety of Fishing Vessels.*

5.7.5.10 Fish-holds gangway and other similar openings are to comply with the following requirements:
(1) fish-holds gangway of both sides of the vessels below working deck and other similar openings shall be fitted with the door open outwards, which are designed to ensure that they have equivalent watertight and structural integrity to the adjacent shell plating. The number of openings above is to be kept to a minimum compatible with the design and proper working of the fishing vessels;
(2) the lower edge of opening mentioned in(1) shall not be lower than the parallel of the side working deck, and the lowest point of the parallel shall be fitted at least 230mm above the top edge of the deepest operating waterline.

5.7.6 **Arrangement of double bottoms**
5.7.6.1 For vessels of 45m in length and over but less than 60m, a double bottom shall be fitted at least between front bulkhead of engine and collision bulkhead or close to these place as far as possible; For vessels of 60m in length and over but less than 75m, a double bottom shall be fitted in the area except engine at least, and that is to be extended to the collision bulkhead and the afterpeak bulkhead or close to these place as far as possible; For vessels of 45m in length and over, a double bottom shall be fitted in the midship that is to be extended to the collision bulkhead and the afterpeak bulkhead or close to these place as far as possible.
5.7.6.2 Where a double bottom is required to be fitted the inner bottom shall be continued out to the vessel's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, h is to be less than *B/20.* However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2,000 mm.
5.7.6.3 A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the vessel is not impaired in the event of bottom or side damage.
5.7.6.4 Small wells constructed in the double bottom in connection with drainage arrangements of fish-holds shall not extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g. for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with the requirements of this section. The vertical distance from the bottom of such a well to a plane coinciding with the keel line shall not be less than 500 mm.

5.7.7 **Arrangement of cofferdams**
5.7.7.1 Cofferdams are to be provided between compartments intended for fuel oil in double bottom and those intended for fresh water for boilers and drinking.
5.7.7.2 Cofferdams are only required between fuel oil tanks in double bottom and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides. Where a corner to corner situation occurs for such tanks, they are not considered to be adjacent.
5.7.7.3 Cofferdams are to be provided between non-edible oil tanks, fish tanks and fresh water tanks; if the spaces between the fish tanks and non-edible oil tanks meet the requirements specified in 3.3.1.2, 3.3.1.3 or 3.3.1.4 of Part 1 of *Rules for Construction of Ocean-going Steel Fishing Vessels*, cofferdams are not needed.

5.7.8 **Arrangement of chain lockers**
5.7.8.1 Spurling pipes and cable lockers are to be watertight up to the deck exposed to weather. However, the bulkhead between separate chain lockers (Figure 5.7.8.1(1)) or the common bulkhead between adjacent lockers (Figure 5.7.8.1(2)) need not be watertight.
5.7.8.2 Where means of access are provided, they are to be closed by a substantial cover and secured by closely spaced bolts.
5.7.8.3 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the manhole covers and securing appliances are to be in consistence with recognized standards (e.g., i) ISO 5894: 2018; ii) China: CB/T4392-2014 “Marine manhole cover”; iii) India: IS 15876-2009 “Ship and Marine Technology manholes with bolted covers”; iv) Japan: JIS F2304: 2015, “Ship’s Manholes” and JIS F2329: 1975, “Marine Small Size Manhole”; v) Korea: KS V ISO 5894: 2012; vi) Norway: NS 6260: 1985 "Manhole cover - overview"; vii) Russia: GOST 2021-90 “Ship’s steel manholes, Specifications”), or equivalent to the watertight manhole covers. The use of butterfly nuts and/or hinged bolts as the securing appliances of manhole covers is prohibited.

5.7.8.4 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances (e.g. steel plates in halves hooked over the spurling pipe tops, or canvas covers lashed) to minimize water ingress.

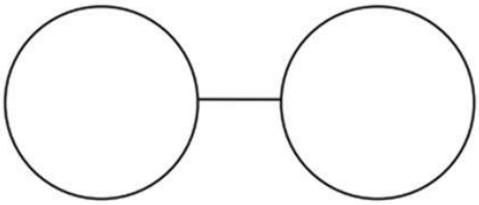


Figure 5.7.8.1(1)

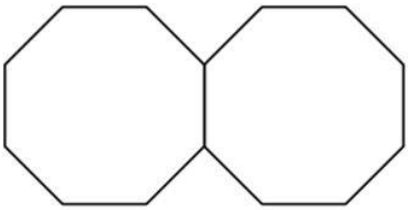


Figure 5.7.8.1(2)

Section 8 FIRE SAFETY

5.8.1 General requirements

5.8.1.1 This Section applies to ocean-going fishing vessels of 24m in length and over.

5.8.1.2 The fire safety of fishing vessels is to meet the requirements of this Section, taking into account the requirements of the flag State Administration, if any.

5.8.1.3 The fire safety of fishing vessels of 45m in length and over is to comply with the relevant provisions of Convention for the Safety of Fishing Vessels.

5.8.2 Plans and documents

5.8.2.1 The following plans and documents are to be submitted for approval or confirmation:

(1) Fire protection zone division plan and typical fire protection node plan;

(2) Fire insulation arrangement plan, deck covering arrangement plan and fire door arrangement plan;

(3) Ventilation system arrangement plan;

(4) Fixed fire extinguishing system arrangement plan and fire extinguishing dose calculation sheet;

(5) Water fire extinguishing system arrangement plan;

(6) Arrangement plan of fixed fire detection and alarm system;

(7) Control system diagram of quick closing valve for fuel and lubricating oil tanks;

(8) Fire control plan;

(9) Other plans and documents considered necessary by ISC.

5.8.3 Product certificate

5.8.3.1 All the main materials, equipment and devices used for fire protection of fishing vessels are to have corresponding ISC product certificates. For details, please refer to the relevant requirements in Appendix 1 B List of Requirements for Certification of Ship's Statutory Products of Chapter 3, Part 1 of this Rules.

5.8.4 Use of substitutes

5.8.4.1 Any special type of equipment, appliance, fire extinguishing agent or device mentioned in this Section may be replaced by other types of equipment without reducing efficiency, but relevant calculation, test or use experience are to be provided.

5.8.5 Fire safety requirements for fishing vessels of 30m in length and over but less than 45m

5.8.5.1 Structural fire protection

(1) The hull, superstructure, decks and deckhouses are to be constructed of non-combustible materials.

(2) The decks and bulkheads separating machinery spaces of category A from accommodation spaces, service spaces or control stations are to be constructed to "A-0" class standard. Decks and bulkheads separating other machinery spaces from accommodation, service spaces and control stations are to be "A-0" class standard. Decks and bulkheads separating the skipper's cabin from the wheelhouse, control stations from accommodation and service spaces are to be constructed to "B" class standard.

(3) The bulkheads of corridors serving accommodation spaces, service spaces and control stations are to be

of "B-0" class divisions.
(4) Any bulkhead of corridor serving accommodation spaces, service spaces and control stations is to extend from deck to deck unless a continuous ceiling of the same class as the bulkhead is fitted on both sides of the bulkhead, in which case the bulkhead may terminate at the continuous ceiling.
(5) Interior stairways serving accommodation spaces, service spaces or control stations are to be made of steel or other equivalent material. Such stairways are to be within enclosures constructed of "B-15" class divisions, provided that, where a stairway penetrates at least two decks.
(6) Doors and other closures of openings in bulkheads and decks referred to in 5.8.5.1 (2) to (4) of this Section, doors fitted to stairway enclosures referred to in 5.8.5.1 (5) of this Section, and doors fitted in engine and boiler casings, are to be as far as practicable equivalent in resisting fire to the divisions in which they are fitted. Doors to machinery spaces of category A are to be self-closing.
(7) Lift trunks which pass through the accommodation and service spaces are to be constructed of steel or other equivalent material and to be provided with means of closing which will permit control of draught and smoke.
(8) The boundary bulkheads and decks of spaces containing any emergency source of power, and bulkheads and decks between galleys, paint rooms, lamp rooms or any store-rooms which contain appreciable quantities of highly flammable materials and accommodation spaces, service spaces or control stations, are to be constructed of "A" class divisions. However, "B-15" class divisions between a galley and accommodation spaces, service spaces and control stations may be accepted when the galley contains electrically heated furnaces, electrically heated hot water appliances or other electrically heated appliances only.
(9) Highly flammable products are to be carried in suitably sealed containers.
(10) When bulkheads or decks required by this Section to be "A" or "B" class divisions, are penetrated for the passage of by electrical cables, pipes, trucks, ducts, etc., arrangements are to be made to ensure that the fire integrity of the division is not impaired.
(11) Air spaces enclosed behind ceilings, panellings or linings in accommodation spaces, service spaces and control stations are to be divided by close-fitting draught stops spaced not more than 7 m apart.
(12) Windows and skylights to machinery spaces are to be as follows:

① where skylights can be opened, they are to be capable of being closed from outside the space. Skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached;

② glass or similar materials are not to be fitted in machinery space boundaries. This does not preclude the use of wire-reinforced glass for skylights and glass in control rooms within the machinery spaces; and

③ wire-reinforced glass is to be used in skylights referred to in 5.8.5.1(12) ① of this Section.

(13) Insulating materials in accommodation spaces, service spaces except domestic refrigerating compartments, control stations and machinery spaces are to be non-combustible. The surface of insulation fitted on the internal boundaries of machinery spaces of category A is to be impervious to oil or oil vapours.
(14) Within compartments used for stowage of fish, combustible insulation are to be protected by close-fitting cladding.

5.8.5.2 Ventilation system

(1) Except ventilators serving spaces in which stoves are installed can have no closing appliances in accordance with 5.8.5.3 (2) of this Section, means are to be provided to stop fans and close main openings to ventilation systems from outside the spaces served .
(2) Means are to be provided for closing, from a safe position, the annular spaces around funnels.
(3) Ventilation openings may be permitted in and under the doors in corridor bulkheads except that such openings are not to be permitted in and under stairway enclosure doors. The openings are to be provided only in the lower half of a door. Where such opening is in or under a door, the total net area of any such opening or openings is not to exceed $0.05m^2$. When such opening is cut in a door, it is to be fitted with a grille made of non-combustible material.
(4) Ventilation ducts for machinery spaces of category A or galleys are not to, in general, pass through accommodation spaces, service spaces or control stations. If the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions, this arrangement can be permitted.
(5) Ventilation ducts of accommodation spaces, service spaces or control stations are not to, in general, pass through machinery spaces of category A or through galleys. If the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions, this arrangement can be permitted.
(6) Store-rooms containing flammable products and exceeding $4m^2$ are to be provided with ventilation

arrangements which are separate from other ventilation systems. Ventilation are to be arranged at high and low levels and the inlets and outlets of ventilators are to be positioned in safe areas. Suitable wire mesh guards to arrest sparks are to be fitted over inlet and outlet ventilation openings.

(7) Ventilation systems serving machinery spaces are to be independent of systems serving other spaces.

(8) Where trunks or ducts serve spaces on both sides of "A" class bulkheads or decks, dampers are to be fitted so as to prevent the spread of fire and smoke between compartments. Manual dampers are to be operable from both sides of the bulkhead or the deck. Where the trunks or ducts with a free cross-sectional area exceeding $0.02m^2$ pass through "A" class bulkheads or decks, automatic self-closing dampers are to be fitted. Where the trunks with a free cross-sectional area exceeding $0.02m^2$ serving compartments situated only on one side of such bulkheads, unless the ducts are of steel in the vicinity of passage through the deck or bulkhead, the openings are to be lined with a steel sheet sleeve and comply in that portion of the duct with the following:

① for ducts with a free cross-sectional area exceeding $0.02m^2$, the sleeves are to have a thickness of at least 3 mm and a length of at least 0.9m. When passing through bulkheads, this length are to preferably be divided evenly on each side of the bulkhead. Ducts or sheet sleeve fitted to these ducts are to be provided with fire insulation. The insulation are to have at least the same fire integrity as the bulkhead or deck through which the duct passes. Equivalent penetration protection may be provided; and

② ducts with a free cross-sectional area exceeding $0.075m^2$ are to be fitted with fire dampers in addition to the requirements of ① above. The fire damper is to operate automatically, but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the bulkheads which they penetrate.

5.8.5.3 Heating installations

(1) Electric radiators are to be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiator are to be fitted with an element so exposed that clothing, curtains or other similar materials can be scorched or set on fire by heat from the element.

(2) Heating by means of open fires are not to be permitted. Heating stoves and other similar appliances are to be firmly secured and adequate protection and insulation against fire are to be provided beneath and around such appliances and in way of their uptakes. Uptakes of stoves which burn solid fuel are to be so arranged and designed as to minimize the possibility of becoming blocked by combustion products and are to have a ready means for cleaning. Dampers for limiting draughts in uptakes are still to leave an adequate area open when in the closed position. Spaces in which stoves are installed are to be provided with ventilators of sufficient area to provide adequate combustion-air for the stove. Such ventilators are to have no means of closure and their position is to be such that closing appliances in accordance with 5.7.5.7 in Section 7 of this Chapter are not required.

(3) Open flame gas appliances, except cooking stoves and water heaters, are not to be permitted. Spaces containing any such stoves or water heaters are to have adequate ventilation to remove fumes and possible gas leakage to a safe place. All pipes conveying gas from container to stove or water heater are to be of steel or other approved material. Automatic safety gas shut-off devices are to be fitted to operate on loss of pressure in the gas main pipe or flame failure on any appliance.

5.8.5.4 Miscellaneous items

(1) Exposed surfaces within accommodation spaces, service spaces, control stations, corridor and stairway enclosures and the concealed surfaces behind bulkheads, ceilings, panellings and linings in accommodation spaces, service spaces and control stations are to have low flame-spread characteristics.

(2) Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke or toxic gases or vapours.

(3) Primary deck coverings within accommodation and service spaces and control stations, are to be of approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.

(4) In accommodation and service spaces and control stations, pipes penetrating "A" or "B" class divisions are to be of approved materials capable of withstanding the temperature required by the division. Due to arrangement reasons, the pipes conveying oil or combustible liquids that pass through accommodation and service spaces are to be approved fire-resistant material.

(5) Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

(6) All waste receptacles, other than those used in fish processing, are to be constructed of non-combustible materials with no openings in the sides and bottom.
(7) Machinery driving fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they can be stopped in the event of a fire arising in the space in which they are located.
(8) Drip trays are to be fitted, where necessary, to prevent oil leaking into bilges.

5.8.5.5 Storage of gas cylinders and dangerous materials

(1) Cylinders for compressed, liquefied or dissolved gases are to be clearly marked by means of prescribed identifying colours, have a clearly legible identification of the name and chemical formula of their contents and be properly secured.
(2) Cylinders containing flammable or other dangerous gases and expended cylinders are to be stored, properly secured, on open decks and all valves, pressure regulators and pipes leading from such cylinders are to be protected against damage. Cylinders are to be protected against excessive variations in temperature, direct rays of the sun, and accumulation of snow. Due to arrangement reasons, such cylinders an be permitted to be stored in compartments complying with the requirements of 5.8.5.5 (3) to (5) of this Section.
(3) Spaces containing highly flammable liquids, such as volatile paints, paraffin, benzol, etc., and, where permitted, liquefied gas, are to have direct access from open decks only. Pressure-adjusting devices and relief valves are to exhaust within the compartment. Where boundary bulkheads of such compartments adjoin other enclosed spaces, they are to be gastight.
(4) Except as necessary for service within the space, electrical wiring and fittings are not to be permitted within compartments used for the storage of highly flammable liquids or liquefied gases. Where such electrical fittings are installed, they are to be approved safety devices. Sources of heat are to be kept clear of such spaces and "No smoking" and "No naked light" notices are to be displayed in a prominent position.
(5) Separate storage are to be provided for each type of compressed gas. Compartments used for the storage of such gases are not to be used for storage of other combustible products nor for tools or objects not part of the gas distribution system.

5.8.5.6 Means of escape

(1) Stairways and ladders leading to and from all accommodation spaces and in spaces in which the crew is normally employed, other than machinery spaces, are to be so arranged as to provide ready means of escape to the open deck and, thence, to the survival craft:

① at all levels of accommodation at least one means of escape is be provided. Where two or more means of escape are provided, they are to be as widely separated as possible, which include the normal means of access from each restricted space or group of spaces;
② a corridor or a part of a corridor from which there is only one route of escape is not to preferably exceed 5 m in length and, in no case, be greater than 7 m in length; and
③ stairways and corridors used as means of escape are not to be less than 700 mm in clear width, and are to have a handrail on one side. Stairways and corridors with a clear width of 1800mm and over are to have handrails on both sides. "Clear width" is considered the distance between the handrail and the bulkhead on the other side or between the handrails on both sides. The angle of inclination of stairways is to be, in general, 45° but not greater than 50° and in machinery spaces and small spaces not more than 60°. Doorways which give access to a stairway is to be of the same size as the stairway.

(2) Two means of escape are to be provided from every machinery space of category A which are to be as widely separated as possible. Vertical escapes are to be by means of steel ladders. Where the size of the machinery spaces makes it impracticable, one of these means of escape may be omitted. Where the length of machinery space of category A is less than 7m, one means of escape can be permitted.

5.8.5.7 Automatic fire detection and alarm system

(1) Where appreciable amounts of combustible materials are used on the construction of accommodation spaces, service spaces and control stations, special consideration are to be given to the installation of an automatic fire detection and alarm system in those spaces, having due regard to the size of those spaces, their arrangement and location relative to control stations.

5.8.5.8 Fire pump

(1) Each fishing vessel is to be equipped with water fire extinguishing system. The minimum number and type of fire pumps to be fitted are to be as follows:

① one power pump not dependent upon the main machinery for its motive power; or
② one power pump driven by main machinery, provided that the propeller shafting can be readily disconnected or provided that a controllable pitch propeller is fitted.

(2) Sanitary, bilge, ballast, general service or any other pumps may be used as fire pumps if they comply with the requirements of this chapter and do not affect the ability to cope with pumping of the bilges. Fire pumps are to be so connected that they cannot be used for pumping oil or other flammable liquids.
(3) Centrifugal pumps or other pumps connected to the fire main through which backflow could occur are to be fitted with non-return valves.
(4) The total capacity of main power-operated fire pumps are to be at least:

$$Q=(0.15\sqrt{L(B+D)}+2.25)^2 \quad m^3/h$$

Where: L——Length, m
B——Breadth, m
D——Depth, m.

(5) Where two independent power-operated fire pumps are fitted, the capacity of each pump is not to be less than 40% of the quantity required by 5.8.5.8(4) of this Section.
(6) When main power fire pumps are delivering the quantity of water required by 5.8.5.8(4) of this Section through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is not to be less than $0.20N/mm^2$.
(7) The emergency fire pump of fishing vessel is to be fitted are to be as follows:

① if a fire in any one compartment could put all the fire pumps out of action, there is generally to be an emergency fire pump. This emergency fire pump can be portable.

② the emergency fire pump is to be capable of delivering water through the jet required by 5.8.5.10 (1) of this Section.

③ the fixed emergency fire pump can be driven by diesel engine or motor, and is to meet the requirements as follows:

—— the emergency fire pump is generally to be capable of maintaining a water jet with a range of 12m and over from the fire hydrant at the highest position of the fishing vessel (the number of fire hydrants is set as the following provision), and the pressure at the hydrant is not to be less than the provisions in 5.8.5.8(6) of this Section;

——when the emergency fire pump runs, the number of fire hydrants used at the same time is not to be less than one;

——the outlet pipe of the emergency fire pump is to be connected to the fire main;

—— the emergency fire pump is to be located outside the engine room and within spaces easily accessible, and be set above working deck as far as possible, and supplied water by an independent submarine valve located outside the main fire pump space.The locations of the pump and its suction are to be such that the pump can still run effectively at the lowest draught that may be encountered in the operation of fishing vessels. The emergency fire pump is to be self-priming;

——if the emergency fire pump is driven by motor, it is to be powered by emergency power supply and the continuous running time is not to be less than 3 hours when the main power supply is cut off;

—— if the emergency fire pump is directly driven by the diesel engine or indirectly driven by the emergency diesel generator set, the diesel engine is to be capable of being readily started in its cold condition down to the temperature of 0℃, and its fuel flash point (closed cup test) is not to be lower than 43℃, and fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 3 h. In addition sufficient reserves of fuel is to be available to enable the pump to be run on full load for an additional 9 h.

④ portable power emergency fire pump is suitable to be driven by diesel engine. fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 3 h. In addition sufficient reserves of fuel is to be available to enable the pump to be run on full load for an additional 9 h. The pump is to be equipped with necessary accessories.

⑤ for the emergency fire pump which is allowed to use portable power, the permanent sea connection device for emergency use is generally to be set outside the machinery space. The use of hose to absorb water directly from the outboard is to be approved by ISC.

⑥ the suction pipeline of emergency fire pump is to be designed to minimize the loss of suction head.

⑦ the emergency fire pump along with its submarine valve and other necessary valves are to be operable from outside compartments containing main fire pumps in a position not likely to be cut off by a fire in those compartments.

5.8.5.9 Fire mains
(1) Where more than one hydrant is required to provide the number of jets specified in 5.8.5.10 (1) of this Section, a fire main is to be provided.

(2) Materials readily rendered ineffective by heat are not to be used for fire mains, unless adequately protected.
(3) Where fire pump delivery pressure can exceed the designed working pressure of fire mains, relief valves is to be fitted.
(4) Fire mains are not to have any connection to any system other than those required for fire fighting, except for the purpose of washing the deck and anchor chains and operation of bilge ejectors, subject to the efficiency of the fire-fighting system being maintained.
(5) Where fire mains are not self-draining, suitable drain cocks is to be fitted where frost damage may be expected.
5.8.5.10 Fire hydrant, fire hose and water nozzles
(1) Fire hydrants are to be positioned so as to allow easy and quick connection of fire hoses and so that at least one jet can be directed into any part of the vessel which is normally accessible during navigation.
(2) The jet required in 5.8.5.10 (1) of this Section is to be from a single length of fire hose.
(3) In addition to the requirements of 5.8.5.10 (1) of this Section, machinery spaces of category A are to be provided with at least one hydrant complete with fire hose and dual purpose nozzle. The fire hydrant is to be located outside the space and near the entrance.
(4) For every required fire hydrant, there is to be one fire hose. At least one spare fire hose is to be provided in addition to this requirement.
(5) Single length of fire hose is not to exceed 20 m.
(6) Fire hoses is to be of an approved material. Each fire hose is to be provided with couplings and a jet /water mist dual-purpose nozzle.
(7) Except where fire hoses are permanently attached to the fire main, the couplings of fire hoses and nozzles are to be completely interchangeable.
(8) The nozzles, as required by 5.8.5.10 (6) of this Section are to be appropriate to the delivery capacity of the fire pumps fitted, but in any case are to have a diameter of not less than 12 mm.
5.8.5.11 A sufficient number of approved portable fire extinguishers are to be provided in control stations and accommodation and service spaces to ensure that at least one extinguisher of a suitable type is readily available for use in any part of such spaces. The total number of extinguishers in these spaces is not to be less than three.
5.8.5.12 Fire-extinguishing appliances in machinery spaces
(1) Water fire-extinguishing system is to be provided in machinery spaces.
(2) Machinery spaces are to be provided with at least a 45L foam extinguisher or its equivalent, so that foam or its equivalent can be directed onto parts of fire hazards.
5.8.5.13 One of the portable fire extinguishers intended for use in any space is to be stowed near an entrance to that space.
5.8.5.14 Fire-extinguishing appliances are to be kept in good order and available for immediate use at all times.

5.8.6 Fire safety requirements for fishing vessels of less than 30m in length

5.8.6.1 Structural fire protection
(1) The hull, superstructure, structural bulkheads, decks and deckhouses are to be constructed of steel or other equivalent materials.
(2) The surface of insulation fitted on the internal boundaries of machinery spaces of category A and spaces where oil products may enter is to be impervious to oil or oil vapours.
(3) All thermal insulation of accommodation spaces is to be constructed of non-combustible materials. Within compartments used for stowage of fish, combustible insulation are to be protected by close-fitting cladding.
(4) Doors between machinery spaces and accommodation spaces are to be steel or other equivalent materials. A door may be allowed between the kitchen and the dining room, but it is to be made of non-combustible materials; the kitchen and the dining room can be regarded as one common lounge and divided into two appropriate cabins where only electrically cooking appliances are fitted in the kitchen.
5.8.6.2 Ventilation system
(1) Ventilation systems serving machinery spaces are to be independent of systems serving other spaces, and the main air inlets and outlets are to be able to be closed from outside the spaces, and the ventilation ducts are not to, as far as possible, pass through other spaces.
(2) Ventilation ducts are to be made of steel or other non-combustible materials.
(3) All power ventilations are to be able to be stopped from easily accessible positions outside the spaces serviced.
5.8.6.3 Heating installations

(1) Electric radiators are to be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiator are to be fitted with an element so exposed that clothing, curtains or other similar materials can be scorched or set on fire by heat from the element.
(2) Heating by means of open fires are not to be permitted. Heating stoves and other similar appliances are to be firmly secured and adequate protection and insulation against fire are to be provided beneath and around such appliances and in way of their uptakes. Uptakes of stoves which burn solid fuel are to be so arranged and designed as to minimize the possibility of becoming blocked by combustion products and are to have a ready means for cleaning. Dampers for limiting draughts in uptakes are still to leave an adequate area open when in the closed position. Spaces in which stoves are installed are to be provided with ventilators of sufficient area to provide adequate combustion-air for the stove.
(3) Open flame gas appliances, except cooking stoves and water heaters, are not to be permitted. Spaces containing any such stoves or water heaters are to have adequate ventilation to remove fumes and possible gas leakage to a safe place. All pipes conveying gas from container to stove or water heater are to be of steel or other approved material. Automatic safety gas shut-off devices are to be fitted to operate on loss of pressure in the gas main pipe or flame failure on any appliance.

5.8.6.4 Miscellaneous items

(1) Exposed surfaces within accommodation spaces, service spaces, control stations, corridor and stairway enclosures and the concealed surfaces behind bulkheads, ceilings, panellings and linings in accommodation spaces, service spaces and control stations are to have low flame-spread characteristics.
(2) Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke or toxic gases or vapours.
(3) Primary deck coverings within accommodation and service spaces and control stations, are to be of approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.
(4) In accommodation and service spaces and control stations, pipes penetrating "A" or "B" class divisions are to be of approved materials capable of withstanding the temperature required by the division. Due to arrangement reasons, the pipes conveying oil or combustible liquids that pass through accommodation and service spaces are to be approved fire-resistant material.
(5) Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.
(6) All waste receptacles, other than those used in fish processing, are to be constructed of non-combustible materials with no openings in the sides and bottom.
(7) Machinery driving fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they can be stopped in the event of a fire arising in the space in which they are located.
(8) Drip trays are to be fitted, where necessary, to prevent oil leaking into bilges.

5.8.6.5 The storage of gas cylinders and dangerous materials is to meet the requirements of 5.8.5.5 of this Section.

5.8.6.6 Means of escape

(1) At least one entrance together with necessary stairways or staircases from all accommodation spaces and in spaces in which the crew is normally employed, other than machinery spaces, are to be so arranged as to lead to the open deck.
(2) At least one means of escape is to be provided from every machinery space of category A.
(3) A corridor or a part of a corridor from which there is only one route of escape is not to exceed 5 m in length.

5.8.6.7 Fire pump

(1) At least one power fire pump is to be provided, which can be driven by independent power or driven by main machinery.
(2) The capacity of fire pump is to be at least calculated according to the following formula, but it is not to be less than 16m^3/h and not to exceed 30 m^3/h in any case.

$$Q=(0.15\sqrt{L(B+D)}+2.25)^2 \quad m^3/h$$

Where: L——Length, m
B——Breadth, m
D——Depth, m.

(3) Sanitary, bilge, ballast or general service pumps may be used as fire pumps if they cannot be often used for pumping oil. If they are occasionally used for lightering or pumping fuel oil, suitable conversion devices are to be installed.

5.8.6.8 Fire mains

(1) Where more than one hydrant is required to provide the number of jets specified in 5.8.6.9 (1) of this Section, a fire main is to be provided.

(2) Materials readily rendered ineffective by heat are not to be used for fire mains, unless adequately protected.

(3) Where fire pump delivery pressure can exceed the designed working pressure of fire mains, relief valves is to be fitted.

(4) Fire mains are not to have any connection to any system other than those required for fire fighting, except for the purpose of washing the deck and anchor chains and operation of bilge ejectors, subject to the efficiency of the fire-fighting system being maintained.

(5) Where fire mains are not self-draining, suitable drain cocks is to be fitted where frost damage may be expected.

5.8.6.9 Fire hydrant, fire hose and water nozzles

(1) Fire hydrants are to be positioned so as to allow easy and quick connection of fire hoses and so that at least one jet can be directed into any part of the vessel which is normally accessible during navigation.

(2) The jet required in 5.8.6.9 (1)of this Section is to be from a single length of fire hose.

(3) In addition to the requirements of 5.8.6.9 (1) of this Section, machinery spaces of category A are to be provided with at least one hydrant complete with fire hose and dual purpose nozzle. The fire hydrant is to be located outside the space and near the entrance.

(4) For every required fire hydrant, there is to be one fire hose. At least one spare fire hose is to be provided in addition to this requirement.

(5) Single length of fire hose is not to exceed 20 m.

(6) Fire hoses is to be of an approved material. Each fire hose is to be provided with couplings and a jet /water mist dual-purpose nozzle.

(7) Except where fire hoses are permanently attached to the fire main, the couplings of fire hoses and nozzles are to be completely interchangeable.

(8) The nozzles, as required by 5.8.6.9 (6) of this Section are to be appropriate to the delivery capacity of the fire pumps fitted, but in any case are to have a diameter of not less than 12 mm.

5.8.6.10 A sufficient number of approved portable fire extinguishers are to be provided in control stations and accommodation and service spaces to ensure that at least one extinguisher of a suitable type is readily available for use in any part of such spaces. The total number of extinguishers in these spaces is not to be less than three.

5.8.6.11 Fire-extinguishing appliances in machinery spaces

(1) Water fire-extinguishing system is to be provided in machinery spaces.

(2) Machinery spaces are to be provided with two foam extinguishers or its equivalent equipment, so that foam or its equivalent can be directed onto parts of fire hazards.

5.8.6.12 One of the portable fire extinguishers intended for use in any space is to be stowed near an entrance to that space.

5.8.6.13 Fire-extinguishing appliances are to be kept in good order and available for immediate use at all times.

CHAPTER 6 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS

Section 1 OPEN-TOP CONTAINER SHIPS ENGAGED IN UNRESTRICTED SERVICE

6.1.1 Application

6.1.1.1 This Section applies to open-top container ships of 500 gross tonnage and over, engaged in unrestricted service.

6.1.1.2 Open-top container ships are to be designed in compliance with IMO MSC/Circ.608/Rev.1.

6.1.1.3 Open-top container ships are to comply with the requirements of this Chapter and in addition, the applicable requirements of the Rules and the requirements of ISC Rules for Materials and Welding.

6.1.2 Definitions

6.1.2.1 For the purpose of this Chapter:

(1) Open-top container ship means a containership especially designed so that one or more of the cargo holds need not be fitted with hatch covers.

(2) Freeboard is the distance between the assigned load line and freeboard deck.

(3) Freeboard deck of open-top container ships engaged on international voyages, for the purposes of Chapters I and II of Annex I of the International Convention on Load Lines, 1966 (hereinafter referred to as the LL 1966), is the freeboard deck according to the LL 1966 as if hatch covers are fitted on top of the hatch coamings.

(4) Maximum sustained speed is defined as the maximum service speed taking into account speed loss due to resistance increase in regular waves. Voluntary speed loss is not taken into consideration.

(5) Minimum ship manoeuvring speed is defined to be the minimum speed which maintains directional control and is consistent with the operating characteristics of the ship.

(6) Green water is sea water other than spray shipped aboard the ship under normal operating conditions.

(7) Hold freeing ports are openings penetrating the hull on both sides of the ship above full load waterline within hold area, fitted with non-return valves through which water in a hold overflows outboard while external seawater will not enter the hold in any case.

(8) Permeability of a space is the percentage of that space which can be occupied by water.

6.1.3 Class notation

6.1.3.1 Open-top container ships complying with the requirements of this Chapter are to be assigned the Open-Top Container Ship class notation.

6.1.4 Plans and documents

6.1.4.1 In addition to the plans and documents specified in the relevant PARTs and Chapters of the Rules, the following are to be submitted for approval:

(1) Calculations of general and local strength of hull in full-load flooded condition;

(2) Calculations of capacity of bilge pumping system.

6.1.5 Freeboard and ship arrangement

6.1.5.1 Minimum freeboard is to be determined by seakeeping characteristics, stability (both intact and damage stability) and structural strength, and the greatest value obtained thereby is to be taken.

6.1.5.2 Seakeeping characteristics are to be obtained by model tests, and the following are to be submitted:

(1) measured data for the maximum hourly rate of ingress of green water likely to be shipped into each cargo hold;

(2) evaluation of the adequacy of the discharge rates from cargo hold freeing ports (if they are fitted).

6.1.5.3 In all loading conditions other than those assuming the hold being flooded, the assigned freeboard and the bow height are to be not less than the corresponding ones determined from the LL 1966 assuming hatch covers being fitted.

6.1.5.4 The assigned freeboard and the bow height according to 6.1.5.3 are to be not less than the corresponding ones for which the model tests are carried out. The maximum hourly rate of ingress of green

water in any one open hold determined from model testing is not to exceed the open hatch area multiplied by 400 mm/h.

6.1.5.5 All seasonal freeboards are to be omitted unless any corresponding seasonal freeboards for which the ship is eligible are greater than the freeboard for which the model tests are carried out.

6.1.5.6 Where an individual hold is fitted with hatch covers, the hold may be simulated as having containers being carried on the hatch covers with no seawater being shipped into the hold during the model test.

6.1.5.7 Container cell guides are to be fitted in the hold, except for ships engaged on short international voyages.

6.1.5.8 The stowage of containers with dangerous goods in ships carrying such containers is to comply with the requirements of 6.1.12 and 6.1.13 of this Section.

6.1.5.9 No freeing port is to be fitted on the hatch coaming of an open hold.

6.1.6 Procedure of model tests

6.1.6.1 The model experiments are to be carried out in long-crested, irregular waves.

6.1.6.2 The Pierson–Moskovitz, JONSWAP or Bretschneider spectrum is to be used for these experiments. Other spectra may be allowed for ships operating in restricted areas only.

6.1.6.3 The wave spectrum generated for the purpose of these experiments is to have a significant wave height of approximately 8.5 m at the most unfavorable realistic wave period (zero crossing).

6.1.6.4 The effect of wind generated spray need not be simulated during the tests.

6.1.6.5 The model experiments are to be carried out for at least the following wave directions:

(1) following seas (0°/360°);

(2) quarter following seas (45°/315°);

(3) beam seas (90°/270°);

(4) quarter head seas (135°/225°);

(5) head seas (180°).

6.1.6.6 The model experiments are to be carried out for at least the following speeds:

(1) maximum sustained speed in head seas and quarter head seas;

(2) minimum ship manoeuvring speed in quarter following seas and following seas;

(3) zero ship speed (dead ship condition) in beam seas.

6.1.6.7 The model experiments are to be carried out with a self-propelled, unrestrained model without the necessity to change course and the time period of each experiment is to correspond to at least one hour real time.

6.1.6.8 The loading condition used for the tests is to correspond at least to the maximum loaded draught with designed trim. If operational trim values differ substantially from designed trim, additional trim values are to be included in the model test programme.

6.1.6.9 The height of centre of gravity (*KG* value) selected is to correspond to the actual value most likely to be encountered during the ship's service. If *KG* values which may be expected during the operation of the ship differ substantially from this selected *KG* value, additional *KG* values are to be included in the model test programme.

6.1.6.10 For each test condition, the cargo hold which ships most water is to be determined by preliminary tests for each combination of heading, trim and *KG*. In running tests for the full duration specified above, this least favorable hold is to be simulated as having no containers, whilst other cargo holds (each cargo hold as a separate entity) may be simulated as completely fully loaded with containers above the line of the weather deck (or hatch coaming where applicable). Containers are not to be used as a means to prevent shipping of water into an empty hold where they are stacked outboard of the open hold. Rain covers for the open holds are not to be simulated in the model tests.

6.1.6.11 In addition to the usual parameters measured (ship motions, ship speed, relative motions, rudder angles, etc.), the volume of water entering all open cargo holds is to be measured for each experiment. The quantities of water taken aboard the model are to be removed and measured after each test run so that the metacentric height, moment of inertia and displacement are not appreciably disturbed by any accumulation of water during the testing programme.

6.1.6.12 Where freeing ports are fitted, an additional model test to comply with 6.1.5.2(2) is to be conducted at a draught which corresponds to the condition of a departing ship fully loaded with cargo and open holds flooded to the static equilibrium level with freeing ports open. A hold permeability of 70% by volume is to be assumed. Tests are to be conducted at zero speed in beam seas to verify that the capacity of freeing ports is such that the ship will not capsize.

6.1.7 Strength and construction

6.1.7.1 The hull strength and structure of open-top container ships are to be calculated and checked in accordance with Chapters 2 and 7 of PART TWO of the Rules.
6.1.7.2 The general and local strength of the hull is to be sufficient in all loading conditions (including those indicated in 6.1.8.2). In loading conditions indicated in 6.1.8.2, the following requirements are to be satisfied:
(1) Where the still water bending moment in flooded condition exceeds the allowable value, or the draught in flooded condition is greater than the scantling draught, the actual still water bending moment and/or draught in flooded condition is to prevail. Hull girder longitudinal strength (including ultimate strength) is to be checked in accordance with Section 2, Chapter 7, PART TWO of the Rules.
(2) Where the draught in flooded condition is greater than the scantling draught, the former is to prevail. Local strength is to be checked in accordance with relevant sections of Chapters 2 and 7, PART TWO of the Rules.
(3) For hull structures forming watertight boundaries of open-top holds, requirements in Section 13 Deep Tanks, Chapter 2, PART TWO of the Rules are to be satisfied, where the design pressure head h is the vertical distance from the calculation point to the highest point of down flooding height specified in 6.1.8.2.
6.1.7.3 When checking the general strength of open-top container ships, the hatch deformation due to hydrodynamic torque need not be considered.

6.1.8 Intact stability
6.1.8.1 The intact stability of the ship is to meet the relevant requirements for container ships of IMO resolution MSC.267(85) "The International Code on Intact Stability, 2008" and the amendments thereto.
6.1.8.2 Unless specified in 6.1.8.1, with all open holds completely filled with water (permeability of 0.70 for container holds) to the level of the top of the hatch side or hatch coaming or, in the case of a ship fitted with cargo hold freeing ports, to the level of those ports, the stability of the fully laden ship in the intact condition is to meet the survival criteria (with factor $S = 1$) in SOLAS II-1, Part B-1, as amended.
6.1.8.3 The intermediate conditions of hold flooding are also to be considered.

6.1.9 Damage stability
6.1.9.1 The damage stability is to comply with the subdivision and damage stability criteria in SOLAS II-1, Part B to B-4, as amended. The top of coamings of open-top holds is to be considered as the location from which downflooding begins.

6.1.10 Open hold bilge dewatering system and freeing ports
6.1.10.1 The bilge pumping system is to have sufficient capacity to pump:
(1) the maximum hourly rate of green water shipped in seagoing conditions as established by the comprehensive model testing;
(2) an amount equal to rainfall of 100 mm/hour regardless of the installation of rain covers;
(3) the hourly amount of shipped green water measured during the seakeeping model tests for the dead ship condition in beam seas, multiplied by safety factor 2;
(4) four-thirds of the amount of water required for fire-fighting purposes in the largest hold;
(5) an amount equal to the capacity required for ships with closed cargo holds,
whichever is the greater.
6.1.10.2 The pumping of hold bilges is to be possible by at least three bilge pumps.
6.1.10.3 At least one of these pumps is to have a capacity of not less than the required capacity as defined in 6.1.10.1 and is to be dedicated to bilge and ballast service only. The pump is to be located in such a way that it will not be affected by a fire or other casualty to the space containing the pumps required in 6.1.10.4 below or the space containing the main source of power and is to be supplied from the emergency switchboard required by SOLAS Reg. II-1/43, as amended.
6.1.10.4 The combined output of at least two further pumps is not to be less than the required capacity as defined in 6.1.10.1. These pumps are to be supplied from the main source of electrical power required by SOLAS Reg. II-1/41, as amended, or any other source of power independent of the emergency switchboard required by SOLAS Reg. II-1/43, as amended.
6.1.10.5 The bilge pumping system, including the piping system, is to incorporate sufficient redundancy features so that the system will be safely operational and capable of dewatering the hold spaces at the required capacity in the event of failure of any one system component.
6.1.10.6 The bilge pumping system is to be arranged to be effective within the limiting angles of inclination required for the emergency source of electrical power by SOLAS, as amended, and bilge wells are to be readily accessible for cleaning.

6.1.10.7 All open cargo holds are to be fitted with high bilge level alarms. The alarms are to initiate visual and audible warnings in the engine room and the manned control locations (navigation bridge, control stations or machinery space) and be independent of bilge pump controls.
6.1.10.8 If the loss of suction prevents the proper functioning of the bilge system, special measures to prevent this are to be considered, for instance, the installation of level indicators.
6.1.10.9 Open cargo hold drain wells are to be designed to ensure unobstructed discharge of water and easy access for cleaning under all conditions.
6.1.10.10 If provided, freeing ports are to be fitted on both sides of each open cargo hold, subject to the following:
(1) The number, size and location of the freeing ports on each side of each open hold are to be sufficient to prevent the accumulation of water above the level defined in 6.1.6.12 of this Section.
(2) Efficient means of closure to prevent the accidental ingress of water are to be provided. Such means are to be operated from above the freeboard deck. In the case of a ship operating in areas where icing is likely to occur, these arrangements are to be suitable to enable the ports to operate efficiently under such conditions.

6.1.11 Fire protection requirements

6.1.11.1 The fire protection system for open-top container holds is to be based on the philosophy of containing the fire in the bay of origin and to cool adjacent areas to prevent structural damage.
6.1.11.2 Open-top container holds are to be protected by a fixed water spray system. The system is to be capable of spraying water into the cargo hold from deck level downward. The system is to be designed and arranged to take account of the specific hold and container configuration. Where necessary a full-scale test may be required.
6.1.11.3 The water spray system is to be able to effectively contain a fire in the container bay of origin. The spray system is to be subdivided, with each subdivision to consist of a ring-line at deck level in an open cargo hold around a container bay.
6.1.11.4 The water spray system is to be capable of spraying the outer vertical boundaries of each container bay in an open cargo hold and of cooling the adjacent structure. The uniform application density is to be not less than 1.1 l/min/m^2. At least one dedicated fire-extinguishing pump for the hold water spray system with a capacity to serve all container bays in any one open-top container hold simultaneously is to be provided. These pumps are to be installed outside the open-top area. The availability of water to the water spray system is to be at least 50% of the total capacity, with adequate spray patterns in the open-top container hold, and with any one dedicated pump inoperable. For the case of a single dedicated water spray pump this may be accomplished by an interconnection to an alternative source through a hose from the weather deck.
6.1.11.5 Whenever a fire detection system is required in the open hold area, the fire detection system is to be designed and arranged to take account of the specific hold and container configuration and ventilation arrangement.

6.1.12 Carriage of dangerous goods

6.1.12.1 Dangerous goods for which “on deck only” stowage is specified in the International Maritime Dangerous Goods Code (IMDG Code), are not to be carried in or vertically above open-top container holds.
6.1.12.2 In addition to the requirements of 6.1.12.1 above, containers with dangerous goods extending more than 1 m above the top of the watertight upper boundary around an open-top container hold and containing liquids, gases or vapors heavier than air and for which “on deck only” stowage is specified, are not to be carried within one container space① horizontally from the boundary of the open-top container holds.
6.1.12.3 Dangerous goods other than those described in 6.1.12.1 above are not to be carried in or vertically above open-top container holds unless such holds are in full compliance with SOLAS Reg. II-2/19, as amended, applicable to enclosed container cargo spaces, as appropriate for the cargo carried.

6.1.13 Segregation of dangerous goods

6.1.13.1 The segregation of dangerous goods for open-top container holds is to comply with Table 6.1.13.1 instead of the table of segregation of freight containers on board container ships contained in section 7.4.3.3 of the IMDG Code.

---

① Defined in 7.4.3.1.1 of the International Maritime Dangerous Goods Code (IMDG Code), i.e. container space is a space of at least 6 m lengthways and at least 2.4 m athwart. See also the latest definition in the IMDG Code.

Table of Segregation of Freight Containers in Holds of Open-Top Container Ships① **Table 6.1.13.1**

Segregation requirement	Vertical			Horizontal							
					Closed versus closed		Closed versus open		Open versus open	
	Closed versus closed	Closed versus open	Open versus open		On deck	Under deck	On deck	Under deck	On deck	Under deck
1 " Away from"	Superimposition allowed	Open above closed allowed, otherwise as open versus open	Not on the same vertical line	Fore and aft	No restriction	No restriction	No restriction	No restriction	One container space	One container space or one bulkhead
				Athwartships	No restriction	No restriction	No restriction	No restriction	One container space	One container space
2 " Separated from"	Not on the same vertical line	As open versus open		Fore and aft	One container space	One container space or one bulkhead	One container space	One container space or one bulkhead	One container space and not in or above the same hold	One bulkhead
				Athwartships	One container space	One container space	Two container spaces	Two container spaces	Two container spaces and not in or above the same hold	One bulkhead
3 " Separated by a complete compartment or hold from"				Fore and aft	One container space and not in or above the same hold	One bulkhead	One container space and not in or above the same hold	One bulkhead	Two container spaces and not in or above the same hold	Two bulkheads
				Athwartships	Two container spaces and not in or above the same hold		Two container spaces and not in or above the same hold		Three container spaces and not in or above the same hold	Two bulkheads
4 " Separated longitudinally by an intervening complete compartment or hold from"	Prohibited			Fore and aft	At least 24 m horizontally and not in or above the same hold	One bulkhead and at least 24 m horizontally ②	At least 24 m horizontally and not in or above the same hold	Two bulkheads	At least 24 m horizontally and not in or above the same hold	Two bulkheads
				Athwartships	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited

Note: ① All bulkheads and decks are to be resistant to fire and liquid.
② Containers are to be at least 6 m from the bulkhead.

CHAPTER 7 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 Additional requirements for pusher tug-barge combinations are given in Section 2, Chapter 7, PART TEN of the Rules.

CHAPTER 8 ADDITIONAL REQUIREMENTS FOR PUBLIC AFFAIR SHIPS

Section 1 GENERAL PROVISIONS

8.1.1 General requirements

8.1.1.1 This Chapter applies to public affair ships. Public affair ships mean ships used for the purpose of government administrative management.

8.1.1.2 Public affair ships are, in addition to provisions of this Chapter, to comply with applicable provisions of other PARTs and Chapters of the Rules.

8.1.1.3 Where special provisions for public affair ships are specified by the Administration of the flag State, such provisions are to be implemented.

8.1.2 Class notation

8.1.2.1 Public affair ships complying with requirements of this Chapter are to be assigned the following class notation:

Public Affair Ship

8.1.3 Hull structures

8.1.3.1 Hull structures are to satisfy the requirements of ISC Guidelines for Hull Structures of Public Affair Ships at Sea.

CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY

Section 1 GENERAL PROVISIONS

9.1.1 General requirements

9.1.1.1 This Chapter applies to ships not specially designed for icebreaking duties and navigating in first year ice conditions, complying with the ice strengthening requirements of PART TWO and PART THREE of the Rules for B1*, B1, B2 and B3 notations and having an independent icebreaking capability. Ships assigned ice class notation B1* in accordance with the provisions of Section 2, Chapter 4, PART TWO of the Rules, already have the capability of independent navigation in ice corresponding to the ice class notation without the assistance of an icebreaker. For ships complying with the requirements of this Chapter, their independent icebreaking capability is to be better than that of the ships assigned B1* notation in accordance with the provisions of PART TWO and PART THREE of the Rules, i.e. having the icebreaking capacity of removing obstacles for other ships navigating in ice.

9.1.1.2 When approaching ice-infested waters, the ship's speed is to be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 kn in areas containing isolated ice floes is to be increased appropriately.

9.1.1.3 The ship is to have a hull form at the fore end adapted to break ice effectively. Bulbous bows are not to be fitted for ships having higher ice class notations. The stern of the ship is to have a form such that broken ice is effectively displaced. Whenever practicable, transverse framing is to be selected. Where it is desired to make provision for tow operations, the bow area is to be suitably reinforced. In addition, local reinforcement is to be made in way of the stern fork.

9.1.2 Class notations

9.1.2.1 For a ship complying with the requirements for ice strengthening and the requirements of this Chapter, the special features notation "Icebreaking" is to be added before its type notation, together with a corresponding ice class notation, e.g. Icebreaking Tug, Ice Class B1.

Section 2 ENGINE OUTPUT

9.2.1 Output of propulsion machinery

9.2.1.1 The output of propulsion machinery of the ship is to be greater than that required for icebreaking as determined in accordance with 9.2.1.2.

9.2.1.2 The output N_1 required for icebreaking is not to be less than that determined in accordance with the following formula:

$$N_1 = 0.736 f_1 f_2 f_3 f_4 [240 B h_0 (1 + h_0 + 0.035 v^2) + 70 S_c \sqrt{L}] \quad \text{kW}$$

where: B — breadth of the ship, in m;

L — length of the ship, in m;

f_1 — coefficient, to be calculated as below and taken not less than 1.0:

$$f_1 = \frac{1.2\,B}{\sqrt[3]{\Delta}}$$

where Δ means displacement, in t, see 4.2.2.2 of Section 2, Chapter 4 of PART TWO of the Rules;

f_2 — coefficient, to be taken as 0.9 for controllable pitch propeller and 1.0 for fixed pitch propeller;

f_3 — coefficient, to be taken as 0.9 when entry angle of the portion of the fore-body below the waterline is 45°or less, and 1.0 when the angle is greater than 45°, and the product $f_2 f_3$ is not to be taken less than 0.85;

f_4 — coefficient, to be taken as 1.1 with bulbous bow and 1.0 without bulbous bow;

h_0 — ice thickness, in m, see Table 4.2.4.2(1) of Section 2, Chapter 4 of PART TWO of the Rules;

v — ship speed, in kn, when breaking ice of thickness h_0, not to be taken less than 5 kn;

S_c — depth of snow cover, in m, not to be taken less than 0.3 m.

Section 3 HULL STRUCTURE

9.3.1 General requirements

9.3.1.1 In respect to the strengthening requirements for ships having an icebreaking capability where the ice load is calculated in accordance with Section 2, Chapter 4 of PART TWO of the Rules, the actual output power of the main engine at MCR is not to be less than that required for icebreaking in Section 2 of this Chapter.

9.3.2 General requirements for side framing

9.3.2.1 Where a frame or longitudinal frame intersects a boundary between two of the hull regions (see Section 2, Chapter 4 of PART TWO of the Rules), the scantling requirements applicable will be those for the greater region.

9.3.2.2 Extent of tripping brackets: B1* — all regions; B1— forward and midship regions; B1 and B3 — forward region.

9.3.2.3 The effective weld area attaching ice frames or longitudinal frames to primary members is not to be less than the shear area for the frames or longitudinal frames.

9.3.3 Ice stringers

9.3.3.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance *s* between such stiffeners is not greater than that determined in accordance with the following formula:

$$s = 17.06 \frac{t}{\eta} \sqrt{\frac{t}{F_l}} \qquad \text{mm}$$

where: t — thickness, in mm, of the primary longitudinal member adjacent to the shell plating.

F_l — longitudinal distribution coefficient, see Table 9.3.3.1.

Table 9.3.3.1

Ice class	F_l		
	Fore	Midship	Aft
B1*	1.00	0.98	0.89
B1	0.87	0.75	0.64
B2	0.78	0.64	0.51
B3	0.68	0.53	0.37

η — coefficient,

for forward region, one of the following values is to be taken, whichever is the least:

$$\eta_1 = 0.653 + 3.217 \frac{\sqrt{P\Delta}}{10^5}$$

$$\eta_2 = 0.876 + 9.908 \frac{\sqrt{P\Delta}}{10^6}$$

$\eta_3 = 1$;

for midship and aft regions, one of the following values is to be taken, whichever is less:

$$\eta_1 = 0.653 + 9.908 \frac{\sqrt{P\Delta}}{10^6}$$

$\eta_2 = 1$.

P — actual output power of the main engine at MCR, not to be less than that required for icebreaking in Section 2 in this Chapter.

Δ — displacement, in t, see 4.2.2.2, Section 2, Chapter 4 of PART TWO of the Rules.

9.3.4 Stem

9.3.4.1 The section moduls W of the stem in the fore and aft direction is not to be less than that determined in accordance with the following formula:

$$W = 1500 F_l^{1.5} \eta^3 \qquad \text{cm}^3$$

where: F_l, η — see 9.3.3.1.

9.3.4.2 The thickness t of side plates of a welded stem constructed as shown in Figure 9.3.4.2 is to be determined in accordance with the following formula:

$$t = 31\eta\sqrt{F_l} \qquad \text{mm}$$

where: F_l, η — see 9.3.3.1.

The dimension of a welded stem is to be determined in accordance with Figure 9.3.4.2.

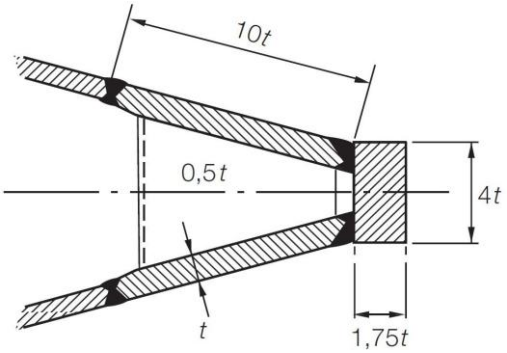


Figure 9.3.4.2 Welded Stem

CHAPTER 10 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS

Section 1 GENERAL PROVISIONS

10.1.1 Application

10.1.1.1 These requirements apply to ships having one of the class notations specified in 10.1.2, specialized in carrying melted petroleum asphalt in bulk in unrestricted service.

10.1.1.2 Unless specified otherwise, asphalt carriers are to comply with the requirements for tankers carrying petroleum products having a flash point exceeding 60℃. Where the maximum cargo temperature cannot be at least 15℃ lower than the flash point of petroleum asphalt, the requirements for tankers carrying petroleum products having a flash point less than 60℃are to be complied with.

10.1.1.3 Calculation of temperature field and analysis of thermal stress required by this Chapter are to comply with the relevant requirements of Section 24, Chapter 2 of PART TWO of the Rules.

10.1.1.4 In the structural calculation of asphalt carriers, the sloshing loads of asphalt cargo need not be considered.

10.1.2 Class notations

10.1.2.1 For classed asphalt carriers fitted with integral tanks and complying with the requirements of this Chapter, the following notation is to be assigned: Asphalt Carrier (Integral tank, Max. Cargo Temperature ≤ XXX℃), F.P. > 60℃, ESP, or Asphalt Carrier (Integral tank, Max. Cargo Temperature ≤×××℃), F.P. ≤ 60℃, ESP.

10.1.2.2 For classed asphalt carriers fitted with independent tanks and complying with the requirements of this Chapter, the following notation is to be assigned: Asphalt Carrier (Independent tank, Max. Cargo Temperature ≤×××℃), F.P. > 60℃ or Asphalt Carrier (Independent tank, Max. Cargo Temperature ≤×××℃), F.P. ≤ 60℃.

10.1.2.3 If requirements of Section 24 of Chapter 2, PART TWO of the Rules are complied with, notation for thermal stress calculation "Thermal stress calculation" may be added.

10.1.2.4 If the arrangement of cargo tanks, including independent and integral tanks, of asphalt carriers comply with the following requirements, Double Hull notation may be assigned:

(1) for asphalt carriers of 5,000 tonnes deadweight and above, the distance *W* between the side plate of the cargo tank or the inner shell of the side tank and the shell plating as well as the distance h between the bottom plate or inner double plate of the cargo tank and the bottom plating comply with the requirements of 1.12.12.1, Section 12, Chapter 1, PART TWO of the Rules;

(2) for asphalt carriers of less than 5,000 tonnes deadweight, the distance *W* between the side plate of the cargo tank or the inner shell of the side tank and the shell plating complies with the requirements of 1.12.12.4, Section 12, Chapter 1, PART TWO of the Rules, and the distance *h* between the bottom plate or inner double plate of the cargo tank and the bottom plating complies with the requirements of 1.12.12.2, Section 12, Chapter 1, PART TWO of the Rules.

10.1.3 Definitions

10.1.3.1 For the purpose of this Chapter:

(1) Petroleum asphalt means co-product of petroleum crude oil extracted to petroleum product such as gasoline, coal oil, diesel oil and lubricating oil, and then treated.

(2) Independent tank means a cargo tank which is not connected with or is not a component part of the hull structure. The independent tank is not necessary to the structural integrity of hull. The independent tank is to be connected to the hull by means of supporting structures to prevent slippage and deflection of the tank. Supporting structures are to include vertical supports, anti-rolling arrangements, anti-pitching arrangements and anti-flotation arrangements.

(3) Integral tank means a cargo tank which is a component part of the hull structure and is subjected to the same load with adjacent portions of the hull structure in the same manner. It is usually necessary to the structural integrity of hull.

(4) Hold space is the space enclosed by the ship's structure in which an independent cargo tank is fitted.

10.1.4 Plans and documents

10.1.4.1 For all petroleum asphalt carriers, the following plans and documents are to be submitted for approval:

(1) Structural plan of cargo tank;

(2) Arrangement plan of cargo tank;
(3) Arrangement plan of heat-insulating material on cargo tank;
(4) Arrangement of means of access for inspections;
(5) Drawing of thermal oil heating system;
(6) Drawings and arrangement diagrams of monitoring and alarm systems related to liquid cargo;
(7) Arrangement of thermal oil boiler room;
(8) Diagram of control system of remotely controlled valve of thermal oil system;
(9) Diagram of fuel oil system of thermal oil boiler.
In addition, the following documents are to be submitted for information:
(1) Cargo information (type and property of cargoes allowed to be carried, e.g. specific gravity, flash point, temperature of cargo being carried, are to be indicated in the "Hull Specification");
(2) Calculations of heat-insulating performance of cargo tank.
10.1.4.2 For petroleum asphalt carriers fitted with integral tanks, the following plans and documents are to be additionally submitted for information:
(1) Calculations for thermal stress analysis of hull structural members (in full and half load conditions), in respect to the temperature of cargo being carried over 80℃.
10.1.4.3 For petroleum asphalt carriers fitted with independent tanks, the following plans and documents are to be additionally submitted for approval:
(1) Arrangement plan of cargo tank and its supporting structures (vertical supports, anti-rolling arrangements, anti-pitching arrangements and anti-flotation arrangements);
(2) Drawing and arrangement diagram of high level alarm system for cargo tank bilge well.
In addition, the following documents are to be submitted for information:
(1) Strength calculations for cargo tank supporting structures;
(2) When temperature of cargo being carried is over 180℃, thermal field distribution calculation of cargo tank is to be submitted. Where the thermal field analysis shows that temperature transmitting to main hull structure is over 80℃, analysis of thermal stress of cargo tank area is to be submitted.

10.1.5 Direct calculation of hull structural strength

10.1.5.1 For longitudinally framed single bottom asphalt carriers 90 m or over in length with independent cargo tanks, primary members (longitudinal and transverse) of the cargo area are to be directly calculated according to Appendix 1 of this Chapter.
10.1.5.2 For asphalt carriers of 150 m or above in length with independent cargo tanks, primary members (longitudinal and transverse) of the cargo area are to be directly calculated according to Appendix 1 of this Chapter.

Section 2 CONSTRUCTION AND ARRANGEMENT OF SHIP

10.2.1 Hull structure

10.2.1.1 The hull structure of asphalt carriers fitted with independent tanks is to comply with the relevant requirements in Chapter 2 of PART TWO of the Rules.
10.2.1.2 The hull structure of asphalt carriers fitted with integral tanks is, as appropriate, to comply with the relevant requirements in Chapters 5 and 6 of PART TWO of the Rules.
10.2.1.3 For asphalt carriers fitted with independent tanks and also with the single bottom of which is longitudinally framed and double sides of which are longitudinally framed, the following requirements are to be complied with:
(1) the minimum thickness: within the cargo tank region, the minimum thickness of primary member webs and face plates, shell plating, deck plating, and inner hull plating is not to be less than that obtained from the following formula:

$$t = 6.5 + L/50 \quad \text{mm, but not less than 7.5 mm}$$

where: L — length of ship, in m, taken not greater than 300 m.
The minimum thickness of secondary structural members are also to comply with the requirements mentioned above, but need not be greater than 11 mm.
The minimum thickness of the members in pump rooms, cofferdams and other void spaces may be 1 mm less than that required above, but not less than 7.5 mm.
(2) shell plating and deck plating: the longitudinally framed shell plating and deck plating of the cargo tank region are to comply with the requirements of Sections 3 and 4, Chapter 2, PART TWO of the Rules respectively;

(3) bottom framing:
(a) The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = \frac{8.5}{1.73 - F_b}(d + h_1)sl^2K \qquad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
l — span of longitudinal, in m, but not less than 1.5 m;
d — draught, in m;
F_b — reduction factor, see 2.2.5.6 of Chapter 2 of PART TWO;
h_1 — see 2.3.1.2 of Chapter 2 of PART TWO;
K — material factor.

The connections of bottom longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. Where higher tensile steels are adopted, longitudinals are to be continuous through the transverse bulkheads. Where the bottom longitudinals are cut in way of the bulkheads, the longitudinals are to be bracketed to the bulkheads. The scantlings of the bracket are to comply with the requirements of 1.2.6 of Chapter 1 of PART TWO, and the flange width of the bracket is not to be less than 8 times the thickness of the bracket.
Bottom longitudinals are to be welded to the web and vertical stiffeners of bottom transverses.
(b) The solid floor is to be spaced not greater than 3.6 m, in line with side transverse web, to form a ring system. The spacing between the center and side keelsons is in general not to be greater than 2.5 m;
The size of solid floors, bottom centerline girder and bottom side girders are to be determined by direct calculation method, which is to comply with the requirements of Appendix 1 of this Chapter.
(c) The web depth of the solid floors is not to be less than 2.5 times the depth of the slot for the bottom longitudinals. The web thickness is not to be less than s/80 (s being the spacing of stiffeners).
The face plate of the solid floor is, within two frame spacing, to be gradually widened to not less than twice its original width at the longitudinal bulkhead, and to be welded to the bulkhead.
(d) The web depth of the bottom centerline girder is not to be greater than that of the bottom transverses. The web thickness of the bottom centerline girder is not to be less than that of the bottom transverses plus 2 mm. The web thickness and face plate scantlings of the intercostal bottom side girders are to be the same as those of the bottom transverses in way, while the depth may be half of that of the bottom transverses. Strengthening and end connections of bottom centreline girder are to comply with the requirements of 6.3.5 of Section 3 of Chapter 6 of PART TWO.
(4) side framing: for double side framing, where the side tanks are used as ballast tanks, the inner hull structure, watertight diaphragms and stiffeners are also to comply with the deep tank requirements of Section 13, PART TWO of the Rules.

10.2.2 Arrangement of ship

10.2.2.1 The hold type of independent tank is recommended.
10.2.2.2 For asphalt carriers fitted with integral tanks carrying cargo at a temperature over 80℃, tank boundaries are not to be in direct contact with seawater.
10.2.2.3 Passages for inspection in independent cargo areas are to comply with the following requirements:
(1) where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements is to be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, is to be at least 450 mm for a curved tank surface, or 600 mm for a flat tank surface (see Figure 10.2.2.3(1));

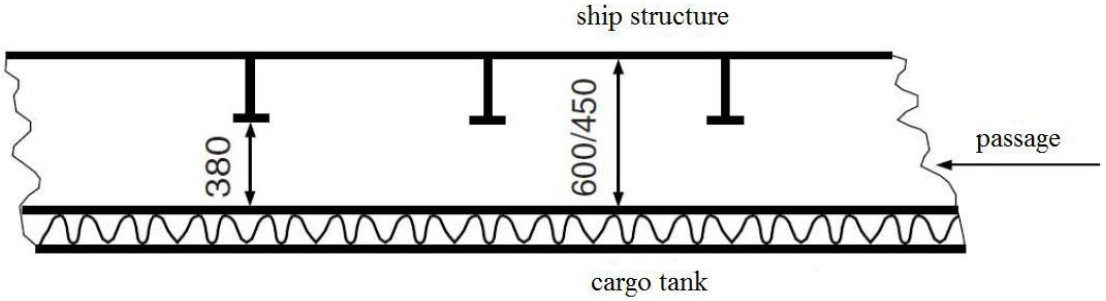


Figure 10.2.2.3(1)

(2) where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected is to be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (see Figure 10.2.2.3(2));

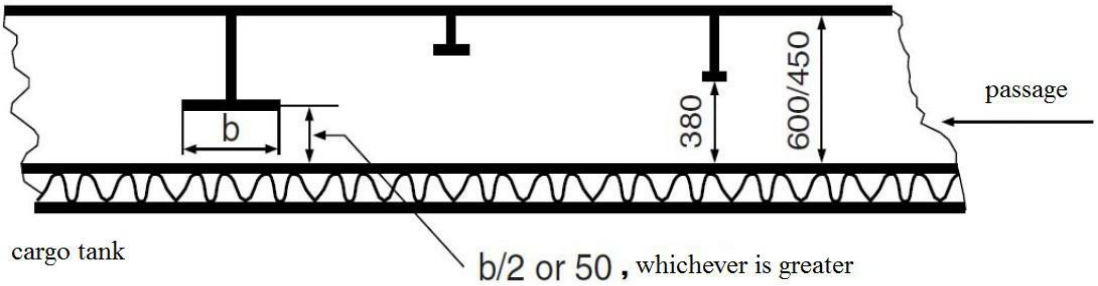


Figure 10.2.2.3(2)

(3) if for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces is to be at least 380 mm (see Figure 10.2.2.3(3)). Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface;

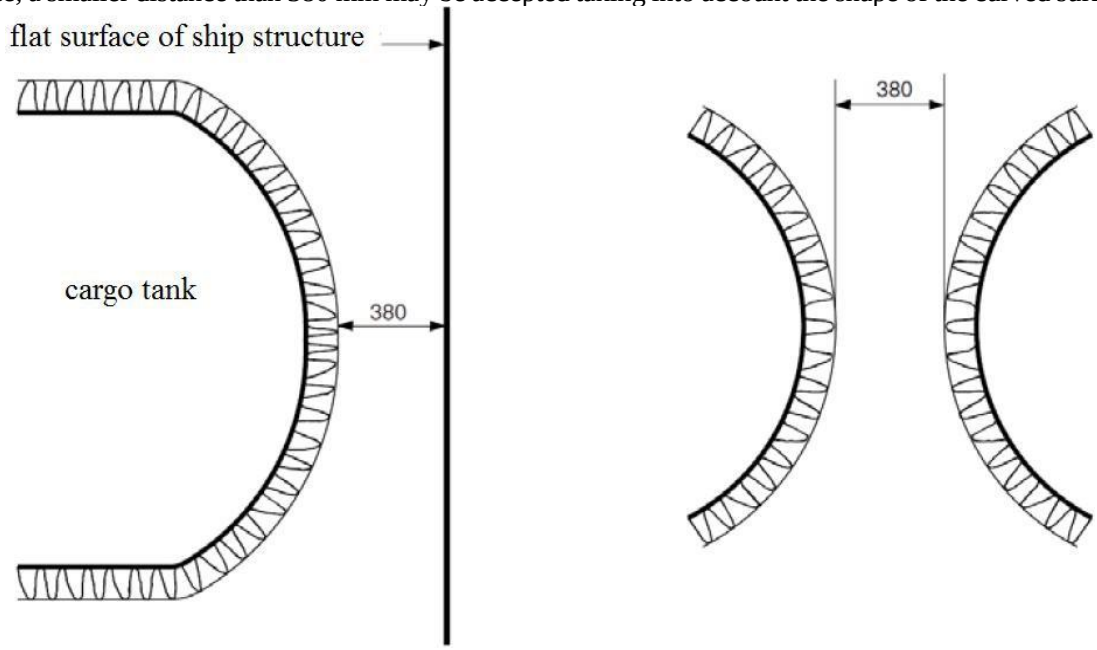


Figure 10.2.2.3(3)

(4) if for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces is to be at least 600 mm. If the plane of inner shell plating (including upper and lower sloping plate) within the double hull has been subject to strict rust cleaning, painted with epoxy resin or other equivalent anti-corrosion paint, and the condition of inner shell plating can be inspected within the double hull, the above mentioned minimum distance may be reduced. Where fixed access ladders are fitted, a clearance of at least 450 mm is to be provided for access (see Figure 10.2.2.3(4));

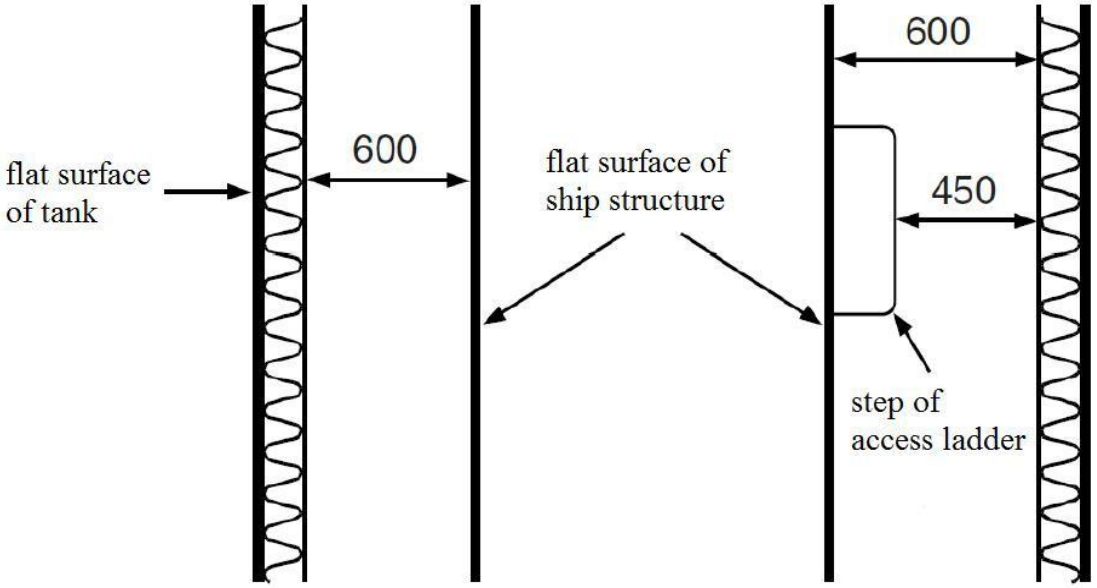


Figure 10.2.2.3(4)

(5) the minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well are not to be less than those shown in figure 3.5 (Figure 10.2.2.3(5) shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm). If there is no suction well, the distance between the cargo tank sump and the inner bottom is not to be less than 50 mm;

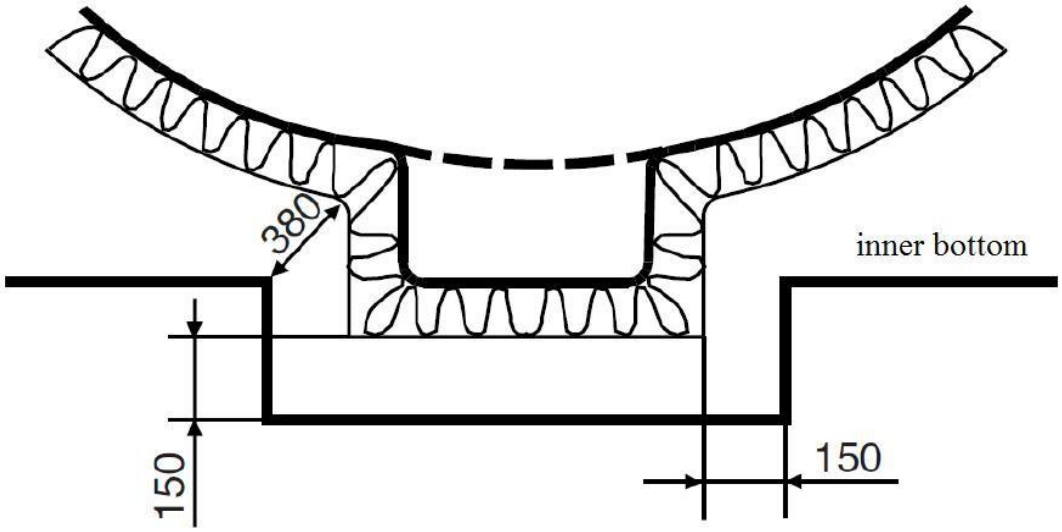


Figure 10.2.2.3(5)

(6) the distance between a cargo tank dome and deck structures is not to be less than 150 mm (see Figure 10.2.2.3(6));

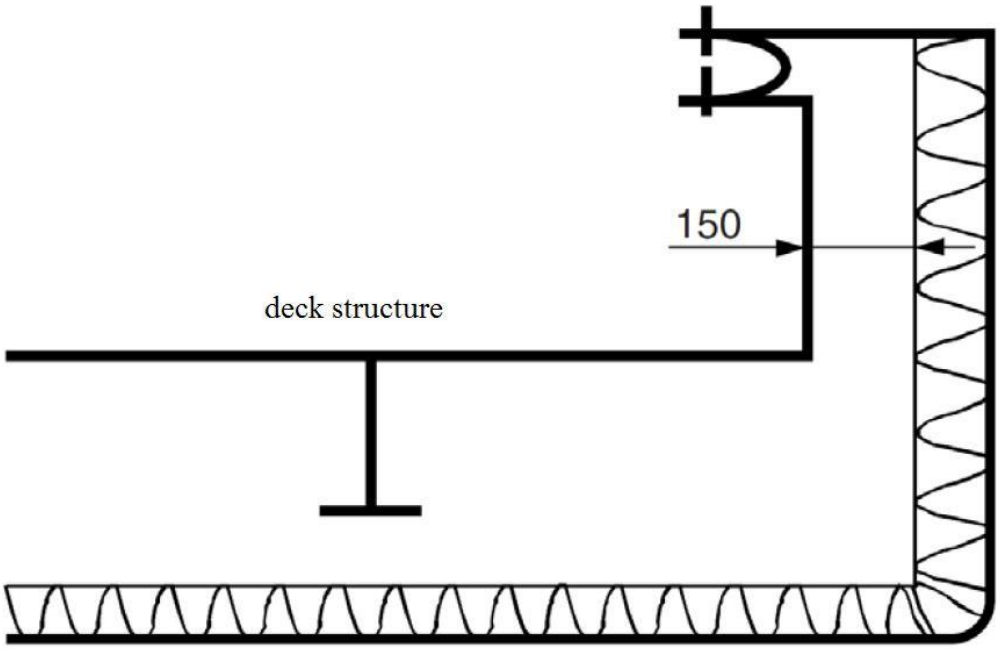


Figure 10.2.2.3(6)

(7) fixed or portable staging is to be installed as necessary for inspection of cargo tanks, cargo tank vertical supports, anti-rolling arrangements, anti-pitching arrangements, anti-flotation arrangements, cargo tank insulation etc. This staging is not to impair the clearances specified in 10.2.2.3(1) to 10.2.2.3(4);

(8) if fixed or portable ventilation ducting is to be fitted, such ducting is not to impair the distances required under 10.2.2.3(1) to 10.2.2.3(4).

10.2.2.4 The corrosion protection of ballast tanks is to satisfy the requirements of Section 6, Chapter 1 of PART TWO of the Rules. In addition, if a ballast tank is adjacent to a cargo tank, epoxy resin or other equivalent anti-corrosion paint is to be coated on the inside bulkheads of such ballast tank.

10.2.2.5 A separate cargo pump room may not be arranged in an asphalt carrier. For asphalt carriers fitted with independent tanks, cargo pumps may be arranged in hold space. For asphalt carriers fitted with integral tanks, if the cargo pump room is adjacent to a cargo tank, heat insulation means or an empty tank is to be provided.

The space where cargo pumps are located is to have good ventilation, normally with 30 to 45 air changes per hour.

10.2.3 Constructional material

10.2.3.1 The independent tank may be of low carbon or higher tensile steel. Considering the decrease of mechanical properties of material caused by high temperature, for members under high temperatures (100℃ and above), the high temperature material coefficient K_T is to be taken as the material coefficient K in the design and is to be calculated as follows:

$$K_T = max\left\{K, \frac{235}{R_{eH}^T}\right\}$$

where: K — material coefficient, see Table 1.3.1.7, Chapter 1, PART TWO of the Rules;

R_{eH}^T — high temperature yield stress, in N/mm², see Table 10.2.3.1.

If the independent tank is of any other material, tensile test is to be carried out to determine the high temperature yield stress R_{eH}^T.

High Temperature Yield Stress under Design Working Temperature R_{eH}^T **Table 10.2.3.1**

	Tensile strength under room temperature R_{eH} (N/mm²)	R_{eH}^T (N/mm²)				
		100℃	150℃	200℃	250℃	300℃
Carbon steel and carbon manganese steel	235	220	210	200	190	180
	315	295	280	265	250	235
	355	330	313	297	282	267
	390	364	344	327	311	295

Note: Intermediate values of the temperature may be obtained by linear interpolation.

10.2.4 Independent tank

10.2.4.1 If the independent tank is mainly of plane construction, its boundary structure is to be designed according to the requirements of 10.2.6, and the design vapor pressure (gauge pressure) is not to be more than 0.07 MPa.

10.2.4.2 Externally insulated independent tanks are to be supported and keyed so as to permit free expansion in all directions and eliminate heat bridges which may transmit thermal stresses to the hull of the ship.

10.2.4.3 The independent tank is to be insulated with an approved heat-insulating material. After the heat-insulating material is laid, the temperature in hold space at ambient temperature (with atmospheric pressure being 1 HPA, air temperature being 0℃ and seawater temperature being 0℃) is not to exceed 180℃.

10.2.4.4 If cargo pumps are located outside the hold space, not less than 20 air changes per hour are to be given in the hold space.

10.2.4.5 Heat-insulating material is to be fixed on the outside surface of the independent tank with welts and wrapped with galvanized steel plate or other equivalent material. Prior to the laying of heat-insulating material, the outside surface of the independent tank is to be coated with high-temperature resistant antirust paint.

10.2.4.6 The independent tank is to be supported by adequate vertical supports such that it is not connected with the hull structure directly. The vertical supports are generally to be of a material with good heat insulation. If the mechanical and physical properties of such material may change at high temperature, effective measures are to be taken to ensure that the mechanical and physical properties will not be decreased significantly.

10.2.4.7 Multi-fulcrum supporting is recommended for the supporting of bottom of the independent tank so as to evenly transfer the weight of the independent tank and the cargo therein to the bottom structure. Supports are to be fitted on primary structural members of the independent tank and hull.

10.2.4.8 Longitudinal and transverse limiting devices are to be provided at suitable positions of the independent tank so that the tank expansion at high temperature will extend in the expected direction.

10.2.4.9 Suitable anti-pitching arrangements are to be provided to withstand a longitudinal collision force acting on the independent tank corresponding to the total weight of the tank and 1/2 cargo in the forward direction and the total weight of the tank and 1/4 cargo in the aft direction without deformation likely to endanger the tank structure. On calculating supporting force, friction force is to be included.

The above-mentioned supports may be taken into consideration together with locating devices.

10.2.4.10 Suitable anti-rolling arrangements are to be provided to prevent the independent tank from slipping transversely and turning over. In general, supports are to be provided at high level to prevent the tank from turning over and stoppers to be provided at low level to prevent the tank from slipping. The stress calculation may be referred to the calculation of cargo securing force as specified in ISC Guidelines for Preparation of Cargo Securing Manual.

The above-mentioned supports may be taken into consideration together with locating devices.

10.2.4.11 In design, loads mentioned in 10.2.4.9 and 10.2.4.10 need not be combined with other stresses.

10.2.4.12 Anti-flotation arrangements are to be provided for independent tanks. The anti-flotation arrangements are to be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the summer load draught of the ship.

The design clearance between anti-flotation arrangements and hull is generally taken between 40 to 60 mm.

10.2.5 Integral tank

10.2.5.1 The boundary structure of the integral cargo tank is to be designed according to the requirements of 10.2.6.

10.2.5.2 For asphalt carriers fitted with integral tanks, hull structural members are to be subject to thermal stress analysis to check the local strength and longitudinal stress in each loading condition. The hull is also to be subject to analysis of temperature field and thermal transmission in full load or half load condition. In the analysis, properties changes of material at high temperature are to be taken into consideration.

10.2.5.3 For spaces of heat-insulating layers of asphalt carriers fitted with integral tanks, provision is to be made to prevent over- or under-pressure caused by temperature variations.

10.2.6 Boundary structure of cargo tanks

10.2.6.1 The thickness t of the tank top plates forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$t = t_0\sqrt{K} + t_c \qquad \text{mm}$$

where: t_0 — thickness, in mm, and whichever greater in the following formulae is to be taken:

$$t_0 = 39.5s\sqrt{P_V - 0.02}$$

$$t_0 = 2.8s\sqrt{\rho h}$$

$$t_0 = 4.5s$$

K — material factor, and the effect of high temperature on the material yield strength is to be considered as appropriate, see 10.2.3.1 of this Chapter;

t_c — corrosion addition, in mm, for carbon steel, t_c = 2.5 mm;

s — spacing of longitudinals, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h — height measured from top of the overflow to the deck, in m.

10.2.6.2 The thickness t of the tank bottom plates and plane bulkhead plates forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$t = t_0\sqrt{K} + t_c \qquad \text{mm}$$

where: t_0 — thickness, in mm, and whichever greater in the following formulae is to be taken:

$$t_0 = 3.95s\sqrt{\rho h_1 + 100(P_V - 0.02)}$$

$$t_0 = 2.8s\sqrt{\rho h}$$

$$t_0 = 2.9s\sqrt{2.45 + h_1}$$

K — material factor, see 10.2.6.1 of this Section;

t_c — corrosion addition, in mm, t_c = 2.5 mm;

s — spacing of stiffeners, in m;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1 — vertical distance measured from the lower edge of the plate to the tank top, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h — vertical distance measured from the lower edge of the plate to top of the overflow, in m.

10.2.6.3 The section modulus W of stiffeners forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae:

$$W = 8Ksl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 4Ks\rho hl^2 \qquad \text{cm}^3$$

$$W = 4.2Ksl^2(2.45 + h_1) \qquad \text{cm}^3$$

where: K — material factor, see 10.2.6.1 of this Section;

s — spacing of stiffeners, in m;

l — span of stiffeners, in m;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1 — vertical distance measured from the mid-point of span of stiffener to the tank top, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h — vertical distance measured from the mid-point of span of stiffener to top of the overflow, in m.

10.2.6.4 The section moment of inertia I of stiffeners forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$I = 2.3\frac{Wl}{K} \qquad \text{cm}^4$$

where: W — section modulus of stiffeners obtained in accordance with 10.2.6.3, in cm^3;

l — see 10.2.6.3;

K — material factor, see 10.2.6.1 of this Section.

10.2.6.5 The section modulus W of plane bulkhead girders forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae

$$W = 11.7Kbl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 6Kb\rho hl^2 \qquad \text{cm}^3$$

$$W = 6.3Kbl^2(2.45 + h_1) \qquad \text{cm}^3$$

l — span of girders, in m;

where: K — material factor, see 10.2.6.1 of this Section;

b — breadth of area supported by the girder, in m;

ρ— the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1— vertical distance measured from the mid-point of span of girder to tank top, in m;

P_V— maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h— vertical distance measured from the mid-point of span of girder to top of the overflow, in m.

10.2.6.6 The section moment of inertia I of plane bulkhead girders forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$I = 2.5\frac{Wl}{K} \qquad \text{cm}^4$$

where: W— section modulus of girders obtained in accordance with 10.2.6.5, in cm^3;

l— see 10.2.6.5;

K— material factor, see 10.2.6.1 of this Section.

10.2.6.7 The thickness t of symmetrical corrugated bulkheads forming part of the boundary structure of cargo tanks is not to be less than the values obtained according to 10.2.6.1. In calculation, s is to be substituted by breadth of corrugation plane a or breadth of corrugation bevel face b, whichever is the greater, and in addition, the following formula is to be complied with:

$$t \geq \frac{s}{70\sqrt{K}} \qquad \text{mm}$$

where: s— breadth of corrugation plane a or breadth of corrugation bevel face b, whichever is the greater, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

K— material factor, see 10.2.6.1 of this Section. For high strength steel grade, the K value of the lower strength steel may be taken from the formula in 10.2.3.1 of this Chapter provided that the plate buckling check requirements (see Section 5, Chapter 1, PART TWO of the Rules) in direct calculation with that lower K value are satisfied.

10.2.6.8 The section modulus W of symmetrical corrugated bulkheads forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae:

$$W = KCsl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 0.50KCs\rho hl^2 \qquad \text{cm}^3$$

$$W = 0.53KCsl^2(2.45 + h_1) \qquad \text{cm}^3$$

where: $W = d_w t(a + \frac{b}{3})$, in cm^3, section modulus of breadth of one corrugation;

s— breadth of one corrugation, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

a— breadth of corrugation plane, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

b— breadth of corrugation bevel face, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

d_w— depth of corrugation, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

t— thickness of corrugated bulkheads, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

K— material factor, see 10.2.6.1 of this Section;

C— coefficient, to be taken according to the end fixity as specified in Table 2.13.3.1, Section 13, Chapter 2, PART TWO of the Rules;

l— span of corrugations, i.e. distance between supporting points, in m;

ρ— the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

P_V— maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h_1— vertical distance measured from the mid-point of span of corrugation to tank top, in m;

h— vertical distance measured from the mid-point of span of corrugation to top of the overflow, in m.

Where the corrugated bulkhead span is more than 15 m, a diaphragm plate is to be fitted near the mid-span point.

10.2.6.9 Where lower stools are fitted, scarfing brackets aligned with vertical webs of corrugated bulkheads are to be provided in the lower stools as far as practicable. Where lower stools are not provided, double bottom floors are generally to be aligned with face plates of vertical corrugated transverse bulkheads, and double bottom girders are generally to be aligned with face plates of vertical corrugated longitudinal bulkheads; scarfing brackets aligned with vertical corrugated webs are to be provided under the inner bottom and hopper as far as practicable. Where transverse bulkheads are in the form of horizontal corrugation, primary members are generally to be aligned with face plates of corrugated bulkheads at the intersection of corrugated bulkheads and inner shell, and longitudinal bulkheads; and scarfing brackets aligned with vertical webs of corrugated bulkheads are to be provided as far as practicable.

10.2.7 Piping

10.2.7.1 Bilge water of hold space is to be discharged overboard by a pump and the pump may be the bilge pump in the machinery space. High-level alarm is to be provided near the bilge suction, audible and visual high-level alarms and controls are to be provided in the navigation bridge and cargo control room (if provided), and it is recommended that such alarm signal and control extend to the central control cabin of the engine room.

10.2.7.2 When the temperature of asphalt needed to be heated is more than that of the saturated vapor, the heating medium is to be hot oil.

10.2.7.3 Cargo pump, cargo piping and cargo operating valve, etc., outside cargo tanks are to be heated.

10.2.8 Electrical installations

10.2.8.1 Electrical installations (except for sensors), cables and attachments are not to be installed in cargo tanks.

10.2.8.2 Cables in the cargo tank necessary to be connected with electrical installations (such as sensors) are not to contact with liquid cargo but to be laid in a gastight steel tube with thick wall.

10.2.9 Monitoring alarm related to liquid cargo

10.2.9.1 The fixed liquid cargo depth detector may be of radar type, capacitance type or pressure type. If radar type depth detector is adopted, other devices or structural members are not to be arranged in depth detecting area.

10.2.9.2 High temperature alarms for liquid cargo are to be provided. When the temperature exceeds the set value, audible and visual alarm is to be given.

10.2.9.3 High level alarms for cargo tanks are to be provided. When the loading level exceeds the high level of normal full loading, an audible and visual alarm is to be given.

10.2.9.4 Temperature monitoring indicator is to be provided outside heat-insulating layer at the bottom of independent cargo tank.

10.2.9.5 Alarm controls and temperature monitoring indicator are to be installed in the liquid cargo control station, and each alarm signal is to extend to the navigation bridge one by one or in a group.

Appendix 1 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF ASPHALT CARRIERS FITTED WITH INDEPENDENT CARGO TANKS

1 General provisions

1.1 Application

1.1.1 This Appendix is applicable to direct calculation of structural strength of asphalt carriers fitted with independent cargo tanks as required in 10.1.5 of this Chapter.

1.1.2 For asphalt carriers to which this Appendix is applicable, the direct strength analysis for cargo tank hull structure, independent tanks as well as supporting structures is to be carried out according to this Appendix.

1.1.3 Where the temperature of carried liquid cargo is above 180℃, the distribution of temperature field of cargo tanks and associated structures is to be calculated through heat transferring analysis. If temperature field analysis indicates that the temperature that is transferred to the main hull structure exceeds 80 ℃ , thermal stress in cargo tank area is to be further calculated, as given in Section 24, Chapter 2, PART TWO of the Rules. Where the actual means of loading may cause relatively big temperature difference for the cargo tank structure (such as asymmetrical loading of two adjacent cargo tanks along the ship breadth, remarkable level difference between two adjacent cargo tanks during loading and unloading operations, as well as alternate cargo loading along the ship's length), thermal stress analysis and calculation may be required in cargo tank area.

1.1.4 For cargo tanks to be partially loaded with other petroleum products, sloshing assessment is to be carried out for cargo tank boundary structure according to ISC Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks. The approved loading limits are to be included in the Loading Manuel as the operation guides.

1.1.5 For those not specified by this Appendix, the applicable requirements in Section 5, Chapter 1 and Appendix 1, Chapter 5 of PART TWO of the Rules are to be complied with.

2 Structural modelling

2.1 Model and element

2.1.1 Normally, the longitudinal extent of the model is to cover the length of 1/2 cargo tank + 1 cargo tank + 1/2 cargo tank within the cargo area amidships, the transverse extent is the full breadth, and the vertical extent is the moulded depth.

2.1.2 The model is to include hull structure, independent tanks as well as supporting structures. However, the global load condition model does not need to include the independent tanks in the fore and aft cargo tank areas as well as supporting structures.

2.1.3 The element is to be meshed according to the provisions in 1.5.6.3 to 1.5.6.6, Chapter 1, PART TWO of the Rules. The supporting structures of the independent tanks are normally designed as not carrying any tension. Therefore, the rigidity of the supporting structures is to be simulated by rod elements but the tensile stress is not to occur in these rod elements.

2.2 Boundary condition

2.2.1 The boundary conditions depend on the model extent and calculation conditions. As the application methods of the global load condition and the local load condition are different, paragraph 4.2, Appendix 1, Chapter 5, PART TWO of the Rules is to be referred to.

3 Loads and conditions

3.1 General requirements

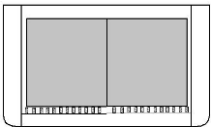
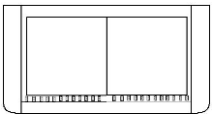
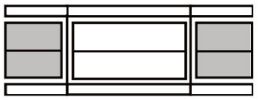
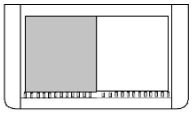
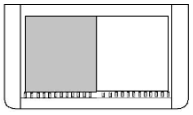
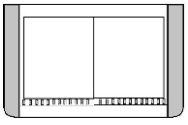
3.1.1 In the assessment condition of cargo tank structure, global load and local load are to be considered, including vertical bending moment, external sea water pressure, liquid pressure of the cargo tank; in the assessment of the supporting structure, the local loads are considered, the inertia force in the forward and aft direction generated by the cargo tank and the cargo due to the collision of hull is assumed, and the upward force acting on the independent tank due to flooding of hull is assumed.

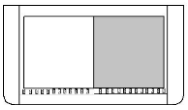
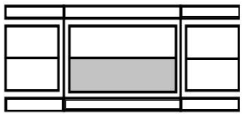
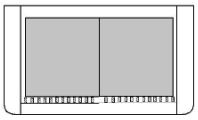
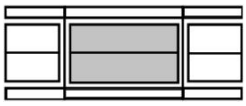
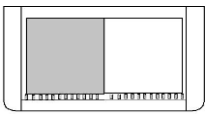
3.1.2 Normally, the hull structure and independent tank structure are to be checked according to the assessment conditions listed in Tables 3.2.1 and 3.2.3. For more severe loading conditions in the loading manual not covered by the tables above, direct calculation of structural strength in those more severe loading conditions are to be carried out.

3.2 Calculation conditions

3.2.1 The tank structural assessment is to be carried out according to the applicable conditions in Table 3.2.1. For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.

Assessment Conditions of Cargo Tank Structure **Table 3.2.1**

<table>
<tr><td colspan="5">Seagoing conditions</td><td colspan="2"></td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC1</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC2</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC3</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC4</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho(g + 0.5 a_v)\ h + 25 f_r$, where a_v is according to 1.5.2.2(8), Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC5</td><td>d_b</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Loading pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td colspan="5">Harbour conditions</td><td colspan="2"></td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
</table>

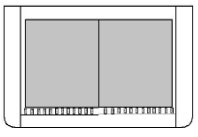
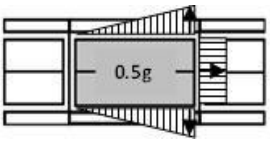
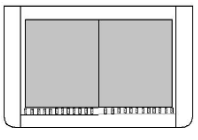
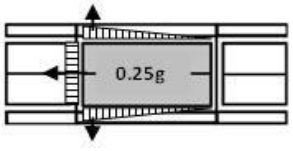
LC6	0.35*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC7	0.35*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC8	0.25*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Note: For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.						

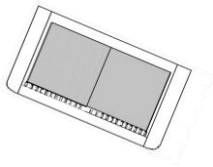
3.2.2 Fine mesh assessment is to be carried out for areas with supporting structures. For possible high stress areas, the element size is to accurately simulate the structural shape. It is recommended that the size is not greater than *s*/8, where *s* is the spacing of members.

3.2.3 The assessment of supporting structures is also to be carried out according to the applicable conditions in Table 3.2.3. All conditions are local load conditions, among which LC1 and LC2 are anti-pitching conditions, LC3 is anti-rolling condition and LC4 is anti-flotation condition.

Assessment Conditions of Supporting Structures

Table 3.2.3

Assessment conditions of supporting structures					
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading
LC1	NA	NA	NA	P_i	 
Internal pressure $P_i = \rho g(h+2.5f_r) + \rho \times (0.5g)x$, for aft bulkhead, *x* is 0, for forward bulkhead, *x* is to be taken as the length of the independent tank					
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading
LC2	NA	NA	NA	P_i	 
Internal pressure $P_i = \rho g(h + 2.5f_r) + \rho \times (0.25g)x$, for aft bulkhead, *x* is to be taken as the length of the independent tank, for forward bulkhead, *x* is 0					
Condition	Draught	Bending	External	Internal	Pattern of loading

		moment	pressure	pressure		
LC3	*d*	NA	P_e	P_i		

NA—Not applicable;

External pressure $P_e = \rho g\left[(d-z)\cos\varphi + |y|\sin\varphi\right]$ starboard side (water entry side)

$= \rho g\left[(d-z)\cos\varphi - |y|\sin\varphi\right]$ port side (water exit side), and not less than 0;

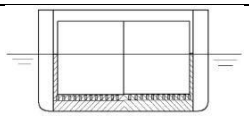
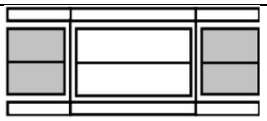
where:

y — transverse distance measured from the considered point to the centreline;

z — vertical distance measured from the considered point to the baseline.

φ — the maximum roll angle, to be taken as not greater than 30°.

Internal pressure $P_i = \rho g(h + 2.5f_r) + \rho \times (0.5g)h_y$, where h_y is the transverse distance from the pressure calculation point to the highest point of the top left corner of the independent tank.

Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC4	d	NA	NA	P_i		

Internal pressure $P_i = \rho g d$

4 Yield and buckling strength assessment

4.1 Yield strength assessment

4.1.1 For hull structures, the stress components generated by the global load condition and local load condition are to be combined to check the strength. For independent cargo tank structures, strength assessment is carried out only to the stress of the local load condition.

4.1.2 See Table 5.1.2, Appendix 1, Chapter 5, PART TWO of the Rules for the permissible stress of each primary member. The permissible equivalent stress of independent cargo tank structures is to be taken as $175/K_T$, for K_T see 10.2.3.1 of this Chapter.

4.1.3 For the refined analysis of the supporting structures assessment condition, the permissible stress is to be taken as follows:

$$\text{permissible equivalent membrane stress} = \begin{cases} 1.4 \text{ times the permissible stress of the cargo tank model,} \\ \quad \text{the element size of the fine area is } s/8 \\ 1.6 \text{ times the permissible stress of the cargo tank model,} \\ \quad \text{the element size of the fine area is } s/16 \end{cases}$$

4.2.1 See paragraph 6, Appendix 1, Chapter 5, PART TWO of the Rules for the requirements for buckling strength assessment.

CHAPTER 11 DYNAMIC POSITIONING SYSTEMS

Section 1 GENERAL PROVISIONS

11.1.1 General requirements

11.1.1.1 This Chapter applies to dynamic positioning (DP) systems installed on board ships or offshore units (hereinafter referred to as vessels).

11.1.1.2 A vessel with a dynamic positioning system, for which no class notation is requested, may be designed and equipped by reference to the applicable requirements of this Chapter.

11.1.1.3 For the equipment or system not complying with the requirements for the class notations, ISC may issue upon request a Declaration of Compliance showing general or partial compliance of the vessel/system with this Chapter. ISC will not monitor or follow up the condition of the vessel thereafter.

11.1.1.4 ISC will give appropriate consideration to novel designs and special functions of dynamically positioned vessels or relevant equipment. If such designs and functions comply with the intention of this Chapter, they are to be accepted.

11.1.1.5 This Chapter is based on the assumption that operation and maintenance of the dynamic positioning system is carried out by qualified crew. This Chapter specifies requirements for drawing submission and technical design.

11.1.2 Class notations

11.1.2.1 When dynamic positioning systems have been designed, constructed and tested in accordance with the requirements of this Chapter and relevant chapters, upon request of the owner and in accordance with different redundancy degrees of the dynamic positioning systems, the following class notations will be assigned:

(1) DP-1: Vessels with dynamic positioning systems can automatically keep their position and heading within specified environmental conditions. Vessels are allowed to lose their position and heading in case of a single failure.

(2) DP-2: Vessels with dynamic positioning systems can automatically keep their position and heading in case of a single failure (excluding loss of a compartment or compartments) within specified environmental conditions and operating limits. Detailed redundancy design principles are given in 11.2.2 of this Chapter.

(3) DP-3: Vessels with dynamic positioning systems can automatically keep their position and heading in case of any single failure, including total loss of a compartment caused by fire or flooding, within specified environmental conditions and operating limits. Detailed redundancy design principles are given in 11.2.2 of this Chapter.

11.1.3 Definitions

11.1.3.1 For the purpose of this Chapter, the following definitions apply:

(1) Dynamic positioning means the provision of a hydrodynamic system with automatic and/or manual control capable of maintaining the heading and position of the ship during operation within specified operating limits and environmental conditions.

(2) Specified operating limits are those for specified allowable position deviations from a set point.

(3) Specified environmental conditions are the specified wind speed, sea current and wave height under which the vessel is designed to carry out its intended operations. Ice load, if any, may be specially considered.

(4) Dynamically positioned vessel is a vessel which automatically maintains its position and heading (fixed location, relative location or predetermined track) exclusively by means of thruster force.

(5) Dynamic positioning system means the complete installation necessary for dynamically positioning a vessel, comprising the following sub-systems:

① thruster system;

② power system;

③ control system and measuring system.

(6) Thruster system means the thrusters and their controls used for dynamic positioning, including:

① thrusters with drive units, including main propellers and rudders if these are under the control of the DP system;

② thruster control system and manual controls;

③ associated cabling and cable routing;

④ auxiliary systems supporting the systems above.

(7) Power system means all components and systems necessary to supply the DP system with power, comprising the following components or systems:

① prime movers;

② generators;

③ switchboards;

④ uninterruptible power supplies (UPSs) and batteries;

⑤ distribution system including cabling and cable routing;

⑥ for DP-2 and DP-3 notations: power management system;

⑦ auxiliary systems supporting the systems above.

(8) DP control system means all control components and systems, hardware and software necessary to dynamically position the vessel. The DP control system consists of the following:

① computer system;

② control stations and display system (operator panels);

③ position reference system;

④ sensor system;

⑤ associated cabling and cable routing;

⑥ networks.

(9) Computer system means a system consisting of one or more computers, including hardware, software, peripherals and interfaces.

(10) Position reference system means the system to measure the ship's position.

(11) Sensor system means a system used to measure parameters such as heading, ship's motion (e.g. rolling, pitching, heaving, etc.), wind velocity and direction.

(12) Position keeping means maintaining a desired position within the normal operating limits of the control system and the environmental conditions.

(13) Loss of position means that the vessel's position and/or heading is outside the limits set for carrying out the DP activity in progress.

(14) Reliability means the ability of a system or component to perform its required function without failure during a specified time interval.

(15) Redundancy means the ability of a component or system to maintain or restore its function when a single failure has occurred. Redundancy can be achieved, for instance, by installation of multiple components, systems or alternative means of performing a function.

(16) Redundancy group means systems simultaneously affected by a single failure, usually categorized as thruster group, power generator group or switchboard group.

(17) Single failure means a failure in a component causing one or both of the following effects:

① function loss of a component or system;

② deterioration of functional capability to such an extent that the safety of the vessel, personnel, or environment is significantly reduced.

(18) Worst-Case Failure (WCF) means the identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the failure mode and effect analysis (FMEA) for class notations DP-2 and DP-3.

(19) Worst-Case Failure Design Intent (WCFDI) means the specified minimum DP system capabilities to be maintained following the worst-case failure. The positioning-keeping capability of a dynamically positioned vessel usually relates to the number of thrusters and generators that can simultaneously fail.

(20) Hidden failure means a failure that is not immediately evident during normal operations or maintenance and has the potential for failure of equipment to perform an on-demand function.

(21) Safe termination time means the minimum amount of time required in an emergency to safely cease and/or evacuate DP operations in process.

(22) Consequence analysis means a software function continuously verifying that the vessel will remain in position if the WCF occurs. An alarm is to be released if positioning is not possible.

(23) Joystick is a device for readily setting of vectorial thrust output including turning moment.

(24) Operational mode is the manner of control under which the DP system may be operated, e. g.:

① automatic operation mode (automatic position and heading control);

② joystick operation mode (manual position control with selectable automatic or manual heading control);

③ manual operation mode (individual control of pitch and speed, azimuth, start and stop of each

thruster);

④ other operation modes, such as autopilot, etc.

11.1.4 Plans and documents

11.1.4.1 For dynamically positioned vessels, the following plans and documents are to be submitted for approval:

(1) Technical description of the DP system, at least including the following:

① function description of the power system and power management;

② system arrangement and configuration: physical separation (DP-3), thruster, switchboard, power generator set, auxiliary system;

③ redundancy groups (DP-2/3);

④ WCFDI (DP-2/3);

⑤ safe termination time (DP-2/3, if applicable).

(2) System diagram of the DP system, including the power arrangement and connection between systems (at least including power unit, control unit, auxiliary system etc.).

(3) Load balance calculations in DP operation. For class notations DP-2 and DP-3, power consumption after the WCF is to be indicated.

(4) Arrangement of the DP control station; arrangement of the back-up control station is also to be included for class notation DP-3.

(5) List of indication and alarm items at DP control consol.

(6) For class notation DP-3, categorization plan of redundancy groups; equipment or systems of different redundancy groups are to be identified in the general arrangement plan in different colours and fire and watertight division between different areas are to be marked in the plan.

(7) For class notation DP-3, cable routing drawing and cable list, where all cables related to the DP system are to be included.

(8) For class notations DP-2 and DP-3, function description of consequence analysis.

(9) For class notations DP-2 and DP-3, failure mode and effect analysis (FMEA) reports.

(10) FMEA redundancy test procedure for class notations DP-2 and DP-3 (to be reviewed by the attending Surveyor).

11.1.4.2 The following plans and documents are to be submitted for information:

(1) Operation manual for the DP system.

(2) Capability analysis of position-keeping, including:

① DP capability when all thrusters are operational, illustrated through description and capability plot;

② for class notations DP-2 and DP-3, DP capability after WCF, illustrated through description and capability plot;

③ environmental conditions are to be categorized using the standard Beaufort scale or other recognized methods;

④ environmental forces (wind, waves, current) and thruster force are to be evaluated by wind tunnel and tank tests or other recognized methods.

11.1.4.3 For novel designs, ISC may raise additional requirements for drawing approval according to the specific design.

11.1.5 Failure mode and effect analysis (FMEA)

11.1.5.1 For class notations DP-2 and DP-3, DP FMEA is required.

11.1.5.2 The purpose of DP FMEA is to analyse and demonstrate whether a DP vessel can keep its position in case of a single failure and whether the system can satisfy the redundancy design intention.

11.1.5.3 The FMEA report is to be a complete and detailed document covering but not restricted to the following:

(1) basic particulars and information of the vessel;

(2) description of system boundary and acceptance criteria;

(3) description of system arrangement and configuration, categorization of redundancy groups, description WCFDI, requirement for safe termination time;

(4) description of all main components of the system and functional block diagram showing interactions between them;

(5) analysis of single failure (including common mode failure, hidden failure), the causes for failures, methods for failure detection, impacts of failures on the DP system locally and globally;

(6) for class notation DP-3, compartment failure analysis (or equivalent methods);

(7) conclusion, which is to include summary of each sub-system and the overall DP system.

11.1.5.4 The test of system redundancy is to be tested under each failure mode. The test program is to be based on the simulation of failure modes, and the tests are to be carried out in the actual DP operation mode.
11.1.5.5 The as-built FMEA(s) and redundancy test program(s) is(are) to be kept on board. The FMEA(s) and redundancy test program(s) is (are) at all times to be updated to cover alterations to the DP system hardware or software, according to the actual condition.

Section 2 SYSTEM ARRANGEMENT

11.2.1 General requirements

11.2.1.1 This Section specifies the requirements for system arrangement of a general type and unless expressly stated otherwise, these requirements apply to all vessels with DP class notations. Specific requirements for each sub-system will be specified below.
11.2.1.2 In accordance with different class notations, the design of DP arrangement is to meet the requirements of Table 11.2.1.2.

Arrangement of DP System **Table 11.2.1.2**

Equipment \ Class notation		DP-1	DP-2	DP-3	
Thruster system	Thruster arrangement	Non-redundant	Redundant	Redundant, separate compartments	
	Manuel control of thrusters	Yes	Yes	Yes (main DP control station)	
Power system	Generator & prime mover	Non-redundant	Redundant	Redundant, separate compartments	
	Switchboard	1	1	2, separate compartments	
	Power management system	-	Redundant	Redundant, separate compartments	
	UPS	1	2	2+1, separate compartments	
Control system and measurement system	Automatic control, number of computer systems	1	2	3 (one located in back-up control station)	
	Independent joystick system	1	1	1	
	Position reference systems	2	3	2 + 1	one located in back-up control station
	Vertical reference systems	1	3	2 + 1	
	Heading sensor systems	1	3	2 + 1	one connected to back-up control station
	Wind speed & direction sensor systems	1	2	1+1	
Back-up DP control station		-	-	Yes	
Alarm printer		1	1	1	

11.2.1.3 Under special environmental conditions for operation, the DP system may be so designed that it has remote control of the length and tension of individual chains where position mooring equipment is used to assist in DP. In accordance with the operation conditions, the consequence of chain fracture or thruster failure is to be analyzed.
11.2.1.4 If external forces from mission-related system (lifting, pipe lay, external fire extinguishing, etc.) have a direct impact on DP performance, the influence of these systems is to be considered and factored into the DP system design.

11.2.2 Redundancy design principles for class notations DP-2 and DP-3

11.2.2.1 To realize the redundancy requirements for the class notations specified in 11.1.2, the DP system is to be arranged as follows:
(1) for class notation DP-2, redundancy of all active components or systems;
(2) for class notation DP-2, redundancy of static components that may immediately affect position keeping capabilities upon failure and is not properly documented with respect to protection;
(3) Active components or systems normally include generator set, switchboard, UPS, thruster, control system, etc. Static components normally include cables, piping, etc.;
(4) If a single operation results in the result exceeding WCFDI, the operation is to be protected, such as double - clicking or additional mechanical protection;
(5) for class notation DP-3, redundancy of all active or static components and A-60 fire separation between the redundancy groups. If such separation is below the damaged waterline, the corresponding watertight separation requirements are also to be met, and the area above the damaged waterline is subject to the FMEA to determine the flooding effect on redundancy and whether watertight separation is required.
(6) When redundancy is considered unnecessary or impossible for some components or systems, further consideration is to be given to the reliability of these components or systems and the effects of failures of them. Where the reliability of these components or systems is sufficient or the effects of failures are

negligible, such specific arrangement may be accepted upon analysis and test results.

11.2.2.2 The system is to be composed of at least two redundancy groups. In case of a single failure (including WCF), redundancy groups are to be immediately available (i.e. hot standby required) and with such quantity, capacity and capability that the DP operation can be continued and/or safely terminated.

11.2.2.3 Restarting the system after it has been fully stopped is not to be considered as the contribution to redundancy concept, which includes but is not limited to thrusters, generator sets, auxiliary systems directly connected to the DP system. Redundancy groups are to be immediately available without the need for manual intervention The transfer of control is to be smooth and changes in position and heading are within acceptable limitations of the operation(s).

11.2.2.4 To prevent failure propagation between different redundant sets, different redundant sets are to be mutual independent from each other, for DP-2 common connections of electrical and pipe systems should be avoided, furthermore for DP-3 common spatial connections should be avoided. If such connections are unavoidable, the influence of fault propagation on different redundant groups is to subject to the FMEA analysis and conclusion is subject to test.

11.2.2.5 For systems which are not directly forming part of the DP system, but may affect the DP system (HVAC systems, common fire suppression systems, ventilator and oil pump remote shutoff, emergency shutdown systems, fire and gas control system, etc.) in the event of activation or failure, they are also to be arranged with adequate redundancy and reliability.

11.2.2.6 If the WCF is obtained according to the FMEA and test result, the result is to be input into the consequence analysis software of the DP control system. Only modes that have been subject to the FMEA and test can be input into consequence analysis.

11.2.2.7 Where the FMEA shows that a hidden failure will result in a loss of redundancy, sufficient and effective measures are to be taken to remind the crew to avoid hidden failures.

11.2.3 Dynamic positioning control station

11.2.3.1 The DP control station for DP operating and controlling is to be fitted on dynamically positioned vessels. The relevant indicators, alarms, control panel and communication system are to be fitted at the control station.

11.2.3.2 The DP control station is to be located such as to suit main operational activities of the vessel and so arranged that the operator has a good view of the vessel's exterior limits and surrounding areas and is aware of any activity relevant to the DP operation.

11.2.3.3 The main DP control station where the DP operator normally operates is to be provided with the following equipment:

(1) DP control system operator station;
(2) independent joystick operator station;
(3) thruster control mode selection devices;
(4) manual thruster levers and indication;
(5) thruster emergency stops;
(6) internal communications; and
(7) position reference systems' HMI.

11.2.3.4 For class notation DP-3, a back-up DP control station is to be fitted. The separation between the back-up control station and the main control station is to meet the requirement of A-60 class fire division. In an emergency, the operator is to be able to easily move from the main DP control station to the back-up DP control station.

11.2.3.5 The back-up control station is to provide a good view of the vessel's exterior limits and surrounding areas. Where physical arrangement cannot satisfy the field of vision requirement, alternative measures such as CCTV may be used, which are to be functional in case that the main DP control station needs to be evacuated.

11.2.3.6 Consideration is to be given to the environmental conditions of the DP control station. If the normal DP operation can be kept only upon necessary measures, redundancy of these measures is required for class notations DP-2 and DP-3.

11.2.4 Display and alarm arrangements

11.2.4.1 The DP control station is to display information from the DP system, to ensure the normal operation of these systems. Information necessary to safely operate the DP system is to be available at all times.

11.2.4.2 Failures of the DP system and the equipment controlled by it are to initiate audible and visual alarms. The occurrence and status of these failures are to be permanently recorded. The record is to be made by means of an alarm printer. If other means are to be used, they are to be subject to special

consideration and with the approval of ISC.

11.2.4.3 Each DP control station is to be fitted with alarms and displays as specified in Table 11.2.4.3.

Alarm and Display at DP Control Station **Table 11.2.4.3**

System	Monitored parameters	Alarm	Display
Thruster system	Combined thrusters force, direction and turning moment(mimic showing the relative position on the vessel)		√
	Individual thruster force, percentage and direction of each thruster (mimic showing the relative position on the vessel)		√
	Thruster allocation mode (fixed, bias, etc.)		√
	Thruster order and feedback indication (including pitch, speed, azimuth etc.)		√
	Load limitation on thruster (overload, insufficient available power, system failure, etc.)	√	
	Thruster status (running, stopped, ready, in command, failure)	√	√
Power system	Status of ACB (including thruster, generator, bus tie as a minimum)		√
	Consumed power and available power of the on-line generator		√
Control system and measurement system	Set points, present position and heading, including the deviation in between		√
	Exceeding operating limits/set point (position, heading)	√	
	Operation status of and position information from position reference system		√
	Position reference system failure	√	
	Operation status of and heading information from heading reference system		√
	Heading reference system failure	√	
	Operation status of and motion information from vertical reference system		√
	Vertical reference system failure	√	
	Operation status of and wind speed/direction information from anemometer		√
	Anemometer failure	√	
	Operation status of consequence analysis software (DP-2/DP-3)		√
	Alarm provided by consequence analysis (DP-2/DP-3)	√	
	Thruster control mode selection device (if computer system) failure, DP control system failure, independent joystick control system failure	√	

11.2.4.4 Where alarms and displays required in 11.2.4.3 are impracticable or unnecessary or equivalent arrangements are available, they may be reduced as appropriate, subject to agreement by ISC.

11.2.4.5 Alarms and displays specified in 11.2.4.3 may be realized by different systems. If one display is used for alarms and other functions, the alarm information is to have higher priority than other information, and is not to be inhibited/overlapped by other information and operations.

11.2.4.6 If the alarms at the DP control station are slave signals of other alarm systems, there is to be a local acknowledgement and silencing device. If the alarms of the thruster system and power system at the DP control station shown in Table 11.2.4.3 are presented as group alarms, the individual alarm is to be indicated locally, however the shutdown alarm is to be separated from other alarm groups. The silence device is not to cause inhibiting of any new alarms.

11.2.5 Arrangement of control panels

11.2.5.1 Indicators and control panels of the DP control station are to be based on ergonomic principles. Indicators and control panels are to be arranged in logical groups, and to be coordinated with the geometry of the vessel when this is relevant. The requirement also applies to indication on displays.

11.2.5.2 Easy switch-over between operational modes are to be provided. Active mode is to be positively indicated. Consistent indications of the operational status of the different sub-systems are to be given.

11.2.5.3 If control of the system and its sub-systems can be carried out from alternate control stations, positive indication of the station in charge is to be provided.

11.2.5.4 The information sources like displays, indicators, etc. are to provide information in a readily usable form. The operator is to be provided with immediate information of the effect of his actions. Generally, feedback signals or other confirmations of actions carried out are to be displayed, not only the initial command.

11.2.5.5 Precautions are to be taken to avoid inadvertent operation of control panels if this may result in a critical situation. Such precautions may be proper location of handles etc, recessed or covered switches, or logic requirements to operations.
11.2.5.6 Interlocks are to be arranged, if erroneous sequence of operation may lead to a critical situation or damage of equipment.
11.2.5.7 Controls and indicators placed in the navigation bridge are to be sufficiently illuminated. Lights for such purpose are to be provided with dimming facilities. Alarm indications is not to be dimmed to zero.

11.2.6 Arrangement of data communication

11.2.6.1 When two or more thrusters and their manual controls are using the same data communication link, this link is to be arranged with redundancy.
11.2.6.2 When the automatic DP control system uses a data communication link, this link is to be separate from the communication link(s) for manual control.
11.2.6.3 For class notations DP-2 and DP-3, the data communication link of the DP control system is to be arranged with technical redundancy and physical separation.
11.2.6.4 The independent joystick system may share the data link with the manual control, but not with the automatic DP control system.
11.2.6.5 For class notations DP-2 and DP-3, a single failure is not to affect the redundant data communication link.

11.2.7 Physical separation arrangement for class notation DP-3

11.2.7.1 A-60 division is to be kept between redundancy groups. If such redundancy groups are below the damaged waterline, adequate watertight separation is also to be ensured. Redundancy groups are composed of equipment, cables and piping systems.
11.2.7.2 For common spaces connected to different redundancy groups, the effects of fire and flooding in such spaces are to be considered. Requirements equivalent to 11.2.7.1 are to be met.
11.2.7.3 Cables for redundant equipment or systems are not to be routed together with those for the main systems through the same compartments. Where this is unavoidable, such cables may run together in ducts of A-60 class fire division provided that this applies only to cables arranged in spaces without high fire risk. Cable connection boxes are not allowed in such ducts.
11.2.7.4 Redundant piping systems (for fuel, lubrication, hydraulic oil, cooling water and pneumatic control) are not to be routed through the same compartment together with the main system. Where this is unavoidable, such pipes may run together in ducts of A-60 class fire division. Such method is only applicable to piping systems not arranged in spaces with high fire risks.
11.2.7.5 The systems, which are not directly part of the DP system, but which in the event of failure could cause failure of the DP system (e.g. common fire suppression systems, engine ventilation systems, shut-down systems, etc.), are also to comply with the relevant requirements of this Chapter.

11.2.8 Internal communication system

11.2.8.1 Two way communication is to be provided between the DP control station and the following locations:
(1) navigation bridge;
(2) engine control room;
(3) control rooms related to DP operations, e.g. cargo control room, drilling control cabin, etc.
11.2.8.2 The power supply of the communication system is to be independent of the main power of the vessel.

Section 3 THRUSTER SYSTEM

11.3.1 General requirements

11.3.1.1 The thrusters mentioned in this Section are pipe tunnel thrusters, azimuth thrusters, thrusters for fixed or variable pitch blades, driven by electric motors, diesel engines, or hydraulically. Other types of thrusters will be specially considered in each case.
11.3.1.2 Unless expressly provided otherwise in this Section, the design and manufacture of the thruster system including prime mover, gearbox, shafting and propeller are to comply with the applicable requirements of PART THREE of the Rules. Electrical installations and automation are to comply with the applicable requirements of PARTs FOUR and SEVEN of the Rules.

11.3.1.3 Thruster systems used in dynamic positioning are to meet the requirements for long-time operations.
11.3.1.4 When the steering gear is included under DP control, it is also to be designed for continuous operation. In DP automatic operation mode, if the rudder is not under control of DP system (not on-line) and not in zero position, an alarm is to be released at the DP control system.

11.3.2 Thruster arrangement
11.3.2.1 The location of thrusters is to be arranged to minimize interference with other thrusters and hull.
11.3.2.2 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.
11.3.2.3 The number and capacity of thrusters are to meet the following requirements:
(1) In the specified environmental conditions, the thruster system is to provide adequate thrust in longitudinal and lateral directions and yawing moment for heading control;
(2) For class notations DP-2 and DP-3, where the arrangement of thrusters is provided with redundancy, there are to be adequate thrust in longitudinal and lateral directions and yawing moment for heading control after failure of any one of the redundant thrusters.
11.3.2.4 If necessary, the values of the thruster forces used in the consequence analysis are to be corrected for interference between thrusters and other effects which will reduce the effective force.

11.3.3 Manual thruster control
11.3.3.1 Manual operation of each thrusters for start, stop, azimuth and pitch/speed control is to be arranged at the DP control station. Azimuth, pitch and speed control are to be non-follow up control.
11.3.3.2 Running, stopped, operation mode, azimuth feedback, pitch feedback and speed feedback status for each thruster is to be continuously and clearly displayed at the DP control station.
11.3.3.3 Failure of the closed loop control system (including feedback devices) is not to affect the indication of azimuth, pitch and speed.
11.3.3.4 It is to be possible to control thrusters manually at all times, also in case failure of DP and independent joystick control systems.
11.3.3.5 Failure of a manual thruster control system including azimuth, pitch, speed control, is not to cause a change in thrust direction and/or an increase in thrust force.
11.3.3.6 It is to be possible to stop thrusters individually from the main DP control station by independent emergency stop devices. The emergency stop of any thruster is not to affect other thrusters. The emergency stop device is to be independent of the DP control system, independent joystick control system and manual thruster control system. The emergency stop is to be arranged with separate cables and control circuit for each thruster.
11.3.3.7 For class notations DP-2 and DP-3, the emergency stop device is to have loop monitoring, including monitoring of power loss, broken wire and short circuit as a minimum. An alarm is to be initiated upon loop failure which is not to affect the running thrusters. For class notation DP-3, the design of the emergency stop device is also to consider the effects of fire and flooding.
11.3.3.8 Alarms related to the thruster system are to be continuously displayed at the manual thrusters control location. Such alarms may arranged to be group alarms, however the shutdown alarm point (if provided) is to be separated from other alarm points.

Section 4 POWER SYSTEM

11.4.1 General requirements
11.4.1.1 Unless expressly provided otherwise in this Chapter, the power system is to comply with the applicable requirements for electrical installations in PARTs THREE and FOUR of the Rules.
11.4.1.2 Automatic load limitation or other automatic measures are to be taken to prevent the active or reactive overload of the power system, in order to prevent partial or total loss of power. This requirement is also applicable to scenario when a single failure leads to tripping of more than one generators (unless there is no generator connected to the bus-bar after the failure). If this requirement is realized by multiple systems, the settings of each system are to be coordinated with each other.
11.4.1.3 For class notation DP-1, the power system needs not to be designed with redundancy.
11.4.1.4 For class notation DP-2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping. The power system(s) may be run as one system during operation, but should be arranged by bus-tie breakers(s) to separate the system automatically upon failures which could be

transferred from one system to another, including, but not limited to, overloading, grounding and short circuits, which is to be identified by failure mode and impact analysis.

11.4.1.5 For class notation DP-3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where the power systems are located below the damage waterline, the separation should also be watertight. But-tie breakers of systems should be open unless equivalent integrity of power operation can be accepted, for detailed principles refer to 11.4.4.7.

11.4.2 Number and capacity of generators

11.4.2.1 When starting thruster motors, especially when one generator is out of service, transient voltage drop caused in the main bus-bar system during starting periods is not to be in excess of 15% of the rated voltage.

11.4.2.2 The high reactive load demands which may occur in DP thruster operation are to be considered when selecting number and type of generators.

11.4.2.3 For class notations DP-2 and DP-3, the redundancy is to be based on the running generator sets, and the number and capacity of generator sets are to meet the requirement for redundancy and capacity after a single failure.

11.4.2.4 Special considerations are to be made when energy storage facilities, such as battery systems, are used to power thrusters during DP operation. Where the energy storage facilities are used as one of the power system redundancy groups of the power system, the corresponding redundancy design principles are to be complied with.

11.4.3 Power management system

11.4.3.1 For class notations DP-2 and DP-3, an automatic power management control system is to be arranged to perform load-dependent starting and stop of generators. This system is to block starting of large consumers when there is not adequate running generator capacity, and to start up back-up generators as required, and hence to permit requested loads start to proceed.

11.4.3.2 The power management system is to satisfy the redundancy requirement of the corresponding notations and is able to maintain power management function after a single failure.

11.4.3.3 An alarm is to be initiated when the total electrical load exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50% and 100% of the running capacity and is to be set with regard to the number of generators in service and the effect of the loss of any one generator.

11.4.3.4 A failure in the power management system is not to cause alteration to the online power generation, and is to initiate an alarm at the crew normal on-watch position in the.

11.4.3.5 It is to be possible to operate the switchboards manually after the power management system stops operation.

11.4.4 Switchboard arrangement for class notations DP-2 and DP-3

11.4.4.1 For class notation DP-2, the switchboard is to be so arranged that no single failure will give a total blackout. A single failure in this case is defined as any system or component breakdown of technical nature. The possibility of short circuit on the bus-bar is to be considered. For vessels with class notation DP-3, single failures also include the failures caused by flooding and fire incidents. The immediate consequence of this is that physical separation of redundant components/systems must be used to limit the effects of flooding and fire incidents.

11.4.4.2 A main bus-bar system is to consist of at least two sections (or parts). Where a circuit breaker is capable of breaking the maximum short circuit current in the system, the sections may be connected with the breaker. This breaker is to be appropriately protected and is to comply with the requirements for selectivity.

11.4.4.3 For class notation DP-2, the switchboard sections of different redundancy groups may be so arranged in one switchboard that adequate capacity is available in case of loss of any section due to any reason and that the vessel's position can be kept within specified environmental conditions and operating limits.

11.4.4.4 For class notation DP-3, switchboards of different redundancy groups are to be isolated from the other(s) by A-60 class fire division. If the switchboards are located below the waterline, the separation is also to be watertight. Adequate capacity is to be available to keep the vessel's position within specified operating limits after loss of any compartments due to fire or flooding. For switchboards of different redundancy groups, there is to be a bus-tie breaker on each side.

11.4.4.5 Power supply for the power system and thruster system need to be originated from their respective redundancy groups and their arrangements need to satisfy the redundancy design principles of the corresponding notations.
11.4.4.6 The online power reserve, i.e. the difference between online generator capacity and consumed power at any time is to be continuously displayed at the DP control station. For split-bus power arrangements, indications are to be provided for individual bus-bar sections.
11.4.4.7 For class notation DP-3, to realize the equivalent integrity required by 11.4.1.5, the following analysis and tests are to be carried out as a minimum:
(1) It is FMEA's responsibility to identify all possible failure modes, failure propagation, consequence of failure; the definition of failure mode is unlimited, including any active, static components failure, common mode failure, hidden failure, loss of an entire compartment due to fire or flooding (including failures of all systems inside the compartment). Computer simulation and other methods are needed to simulate the dynamic response of the DP system during failure condition.
(2) When the FMEA identifies that the occurrence of some failure modes will directly affect positioning, at least two sets of protection are to be provided for this failure mode, and the two sets of protection are to be mutual independent from each other. When both protection are performed, the result cannot exceed the WCFDI.
(3) Automatic blackout recovery of bus-bar of each section and start of all thrusters (except for the faulty bus-bar) need to be arranged. Except manual enabled thrusters into DP control, all other functions must be automatic. The recovery times is to be as fast as possible, and in any case should not exceed 60 seconds, such function is to be verified onboard.
(4) Test need to be carried out according to the FMEA conclusion, in order to verify the functionality of the protection, failure ride through capability, independence between protection function, coordination between various protection and failure monitoring. The test scope is to be defined according to the result of the FMEA, computer simulation and calculation, is to include at least live test such as short circuit, earth fault, governor fault, AVR fault, phase imbalance and PMS fault. The test results need to be recorded and compared with the theoretical analysis to determine whether each case can be accepted.

11.4.5 Control power

11.4.5.1 The computer system, operator station, position reference system, sensor system and printers for DP control system are to be supplied from UPSs. The arrangement and number of UPSs are to be in accordance with Table 11.2.1.2 of this Chapter.
11.4.5.2 For class notation DP-1, at least one UPS is to be provided. For class notations DP-2 and DP-3, the number of UPS is to be determined according to the FMEA results. For class notation DP-2, at least two UPSs are to be provided; for class notation DP-3, at least three UPSs are to be provided, one of which is to be located in a separate compartment separated by A-60 class division from other UPSs.
11.4.5.3 For class notations DP-2 and DP-3, the power supply to the computer system, operator station, position reference system, sensors are to be distributed according to the redundancy design principle to ensure the capability to keep DP position in case of a single failure of the UPS system.
11.4.5.4 For class notation DP-2, the power supply to the redundant UPS is to be derived from different parts of the main switchboard. For class notation DP-3, the power supply to the redundant UPS for the main DP control system is to be derived from different parts of the main switchboard. A single failure cannot cause simultaneous power loss of main and back-up DP control systems.
11.4.5.5 The power supply for the independent joystick system is to be independent of UPS for the DP control system.
11.4.5.6 For the thruster system and power system, the power supply for UPS is to be derived from different redundancy groups if the control power of such systems is supplied by UPS.
11.4.5.7 The battery capacity of each UPS is to be maintained at least 30 min. Alarms are to be initiated in case of charging failure.

Section 5 CONTROL SYSTEM AND MEASURING SYSTEM

11.5.1 General requirements

11.5.1.1 Unless expressly provided otherwise in this Chapter, control systems and measuring systems are to comply with the applicable requirements for automation system in PART SEVEN of the Rules.
11.5.1.2 The control systems and measuring systems of this Chapter includes the following equipment and functions:
(1) DP control system;

(2) independent joystick controls;
(3) thruster control mode selection device.

11.5.2 Arrangement of control systems

11.5.2.1 For class notation DP-1, one DP control system and one independent joystick system with automatic heading control are to be fitted.

11.5.2.2 For class notation DP-2, a redundant DP control system and one joystick system with automatic heading control are to be fitted. Should one automatic DP control system fail, control is to be automatically transferred to another one.

11.5.2.3 For class notation DP-3, triple redundant DP control systems and one joystick system with automatic heading control are to be fitted. The two automatic DP control systems are to be arranged such that, should one fail, control is automatically transferred to another one. The third automatic DP control system is to be located in the back-up control station and transfer of control to it is to be initiated in case of failure of both main control systems.

11.5.2.4 Where two or more computer systems are operated simultaneously, means are to be provided for self-monitoring and comparison between systems so as to initiate an alarm when any significant difference is detected in orders for thrusters or positions or heading. This function is not to endanger the independence of each system or cause any risk of the common mode failure.

11.5.3 Automatic DP control

11.5.3.1 The DP control system is to have thrusters automatic operation mode and is able to keep vessel's position/heading, the set points for position/heading can be selected individually.

11.5.3.2 The DP control system located in the main DP control station is to have joystick operation mode.

11.5.3.3 The relative or absolute position and heading of the ship are to be displayed, including deviations from set points. Audible and visual alarms are to be initiated when the ship deviates from the set points.

11.5.3.4 The automatic DP control is to consist of one or more computer system, comprising processing units, input/output devices, and storage devices.

11.5.3.5 The computer systems are to perform self-check routines for detection of failure. Alarms are to be initiated when critical failures are detected.

11.5.3.6 Each DP computer system is to be isolated from other on-board computer systems and communication systems to ensure the integrity of the DP system. This isolation may be fulfilled via hardware, software systems or physical separation which based on specific design.

11.5.3.7 For class notation DP-1, the following requirements are to be complied with:

(1) The computer system for automatic thruster control is to give pitch/speed and azimuth commands. These commands are transmitted to the individual thruster control units.

(2) The computer system is to perform self-check routines that are to bring the computer system to stop when critical failure conditions are detected.

(3) When stopped, either by automatic or manual means, the computer system is to set speed/pitch commands to zero.

(4) The computer system and operator station of the DP control system is not required to be redundant.

11.5.3.8 For class notation DP-2, the following requirements are to be complied with:

(1) applicable requirements under 11.5.3.7.

(2) Redundant computer systems are to be arranged with automatic command transfer after a detected failure in one of the computer systems and an alarm is to be initiated. Common facilities, such as self-checking routines, data transfer arrangements and interfaces, are not to cause the failure of two/all systems.

(3) One computer system may be selected as the on-line system and other systems are in hot standby condition. The changeover from one system to another is able to be manually and automatically. In case of automatic changeover upon failure detection, the system that was online is to remain unavailable after repair, and it can be selected to be online only manually.

(4) The automatic transfer of control from one computer system to another is to be smooth and the position/heading excursion is to be within the acceptable limitations of the operation.

(5) The above requirements are also applicable to the operator station located at the DP control station.

(6) If any failure of a standby DP control system, the standby sensors or position reference systems connected to it, an alarm is to be initiated.

(7) When a computer system consists of three or more computers, an online voting algorithm maybe used to determine the failed computer and automatically switchover is to be carried out.

11.5.3.9 For class notation DP-3, the following requirements are to be complied with:

(1) applicable requirements under 11.5.3.8.

(2) The back-up DP control system is to be located in a compartment, separated by A-60 division from the main DP control system.
(3) If three independent computer systems are chosen for the main system, one of these computers may serve as the back-up, provided that the necessary independence as required for the back-up is achieved.
(4) There is to be at least one position reference system and one sensor system connected to the back-up system, independent of the main system.
(5) During DP operation, this back-up control system is to be continuously updated by input from the sensors, position reference systems, thruster feedback, etc., and to be ready to take over control.
(6) The back-up computer control system is to have real-time communication with the computer system of the main DP control system. An alarm is to be initiated if any significant difference of parameter is detected or the back-up control station is not ready to take control.
11.5.3.10 For class notations DP-2 and DP-3, the computer system is to include a software function, known as online consequence analysis which at least fulfills with the following requirements:
(1) to continuously verify that the vessel will remain in position even if the WCF occurs under the current environmental conditions. If the left thrusters cannot generate the same resultant thruster force and moment as required before the failure, the consequence analysis is to initiate an alarm.
(2) to calculate the effects of available power of the generator sets and thruster sets on positioning after the WCF, and the principles in 11.2.2.7 of the Chapter need to be followed.
(3) For operations which will take a long time to safely terminate, the consequence analysis is to include a function which simulates the thrust and power remaining after the WCF, based on manual input of weather information.
(4) When other forms of energy storage devices are used as redundancy groups of the DP system, such as battery systems to power thrusters, consequence analysis is to consider the relationship between the time required to safely terminate the operation and the duration of energy storage devices, and the consequence analysis alarm setting is to be less than the expected discharge time.
(5) The operation status of the online consequence analysis is to be continuously and clearly displayed at the DP control station.

11.5.4 Independent joystick control

11.5.4.1 The joystick is to enable the control of longitudinal and transverse thruster forces, turning moments, and all combinations of these thruster force components. The system is to include selectable automatic heading control.
11.5.4.2 The independent joystick control system is to be independent of the DP control system. In case of any failure of the DP control system, independent joystick control of all thrusters is still to be able to be performed.
11.5.4.3 Any failure in the independent joystick control system is to initiate an alarm.
11.5.4.4 Any failure causing operator loss of control of the thrusters in the independent joystick control system is to set the thrust commands to zero. If the failure affects only a limited number of thrusters, the command to these affected thrusters is to be automatically set to zero, while keeping the other unaffected thrusters in joystick control.

11.5.5 Thruster control mode selection device

11.5.5.1 The command transfer between different control systems (e.g. manual thruster control system, DP control system, independent joystick control system, etc.) for thrusters is to be selectable by a simple device located in the DP control station. The device may consist of a single selector switch, or individual selectors for each thruster.
11.5.5.2 In the DP or independent joystick mode, the mode selection device is to be so arranged that it is always possible to select manual controls of thrusters after any single failure in the DP control mode.
11.5.5.3 For class notations DP-2 and DP-3, the mode selection device is to be so designed that no single failure will deselect all thrusters from the automatic operation mode. The results are not to exceed the WCF defined by the system.
11.5.5.4 For class notation DP-3, it is to be possible to transfer the command responsibility to the back-up control at the DP back-up control station, and the mode selection device failure (electrical failure, fire, etc.) will not result in simultaneous failure of the main or back-up DP control.

11.5.6 Position reference systems

11.5.6.1 The position reference systems are to produce position data with adequate accuracy for the intended DP operation to satisfy the corresponding operational requirements.
11.5.6.2 For class notation DP-1, at least two independent position reference systems are to be provided.

11.5.6.3 For class notations DP-2 and DP-3, at least three position reference systems are to be installed. For class notation DP-3, one of the position reference systems is to be connected to the back-up DP control station and separated by A-60 class fire division from other position reference systems.
11.5.6.4 The position reference systems' HMI is to be arranged at the DP control station, which can display the position information and operation status. The HMI is to be independent from the DP operator station. For class notations DP-2 and DP-3, the arrangement for the HMI is to meet the corresponding redundancy requirements. For class notation DP-2, at least two sets of HMI are to be arranged, and for class notations DP-3, one more set of HMI is to be arranged in the back-up control station.
11.5.6.5 For class notations DP-2 and DP-3, the position reference systems' power supply, signal transmission and interface with the DP control system are to meet the system's redundancy arrangement and separation requirements.
11.5.6.6 When two or more position reference systems are required, they are to be based on different principles. For class notation DP-1, if only one principle is used, the design is subject to special consideration and approval from ISC.
11.5.6.7 The data of the position reference systems are to be processed. In case of abnormal conditions such as freezing, jumping, fluctuation or decreased accuracy, such data are to be rejected by the control system through certain means and an alarm is to be initiated. This requirement applies to all online and stand-by position reference systems.
11.5.6.8 The operating status of the position reference systems are to be clearly indicated, such as running, online, failure, and rejected by the control system.
11.5.6.9 When one or more position reference systems are selected/dis-selected, the output of the thrusters should not change significantly. When the last reference system is lost, the output of the thrusters should not change significantly immediately.
11.5.6.10 When an acoustic reference system is used, a hydrophone is to be chosen to minimize the influence of mechanical and acoustic disturbance on transmission channels.
11.5.6.11 When a taut wire system is used, materials used for wire rope, tensioning and auxiliary equipment are to be appropriate for marine service.
11.5.6.12 When the signals from the position reference system are changed by the movement of the vessel (rolling, pitching), the position is to be automatically corrected.
11.5.6.13 The electrical and mechanical parameters of the position reference systems, such as energy, pressure and temperature, are to be monitored and the failure of the position reference systems are to be monitored in so far as practicable.

11.5.7 Sensor systems

11.5.7.1 The sensor systems are to produce heading and other necessary data with adequate accuracy for the DP operation to satisfy the corresponding operational requirements.
11.5.7.2 Sensors are to be provided in accordance with the requirements of Table 11.2.1.2 of this Chapter.
11.5.7.3 For class notations DP-2 and DP-3, where the DP control system relies on the correction signals of sensors, at least three systems are necessary for the same type of sensors.
11.5.7.4 For class notation DP-3, one of the sensor systems is to be directly connected to the back-up control system and separated from the other sensors by A-60 class fire division.
11.5.7.5 For class notations DP-2 and DP-3, the sensor systems' power supply, signal transmission and interface with the DP control system are to meet the system redundancy arrangement and separation requirements.
11.5.7.6 The data of the sensor systems are to be processed. In case of abnormal conditions such as freezing, jumping, fluctuation or decreased accuracy, such data are to be rejected by control system and an alarm is to be initiated. This requirement applies to all online and stand-by sensor systems.
11.5.7.7 The operating status of the position reference systems are to be clearly indicated, such as running, online, failure, and rejected by the control system.
11.5.7.8 The electrical and mechanical parameters of the sensor systems, such as energy, pressure and temperature, are to be monitored and the failure of the sensor systems are to be monitored in so far as practicable.

CHAPTER 12 IN-WATER SURVEY ARRANGEMENTS OF SHIPS

Section 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 This Chapter applies to ships classed with ISC and intended to be assigned the In-Water Survey class notation.

Section 2 DOCUMENTATION TO BE SUBMITTED

12.2.1 Plans/Manuals

12.2.1.1 Detailed plans of the hull and hull appendages below the waterline are to be submitted for approval. These plans are to indicate the location and/or general arrangement of:

(1) all shell openings;
(2) stem and sternpost;
(3) rudder and fittings;
(4) propeller, including the means used for identifying each blade;
(5) anodes, including securing arrangements;
(6) bilge keel;
(7) welded seams and butts;
(8) marking system.

12.2.1.2 The drawings are also to include the necessary instructions to facilitate the divers' work, especially for taking clearance measurements.

12.2.1.3 A plan for evaluating rudder pintle and bearing clearances while the ship is afloat is to be submitted for examination and approval.

12.2.2 Photographs

12.2.2.1 As far as practicable, a photographic documentation, used for reference during in-water surveys, of the following hull parts is to be submitted:

(1) propeller boss;
(2) rudder pintles, where clearance is measured;
(3) typical sea connection;
(4) adjustable propeller, if any;
(5) other details, as deemed necessary on a case by case basis.

12.2.3 Documentation on board

12.2.3.1 The plans and photographs required in 12.2.1 and 12.2.2 are to be kept on board by the owner and made available to the Surveyor and the divers when an in-water survey is carried out.

Section 3 STRUCTURAL DESIGN PRINCIPLES

12.3.1 Marking

12.3.1.1 Identification marks and system are to be supplied to facilitate the in-water survey. The following positions are at least to be included:

(1) ship bottom: connections of bulkhead or watertight floors and girders;
(2) both sides: in way of watertight transverse bulkheads and connections of inner bottom plating to watertight floors.
(3) all shell plating openings below the waterline.

12.3.1.2 The marking is at least to be 300 mm in length and 30 mm in width, which is to be painted in a contrasting colour. The marking may be made in the form of a raised character or made using any other equivalent method which ensures that the marking is not easily expunged. The marking may be replaced by the anodes (e.g. zinc blocks) or external appendages on the hull, provided that they are indicated accordingly in the plans/manuals submitted for approval in accordance with 12.2.1.

12.3.2 Rudder arrangements

12.3.2.1 Rudder arrangements are to be such that rudder pintle clearances can be checked while the ship is afloat.

12.3.3 Oil sealing glands of propeller shafts or tube shafts

12.3.3.1 The oil sealing glands of propeller shafts or tube shafts is to be such that clearances between propeller shafts or tube shafts and bearings can be checked while the ship is afloat.

12.3.4 Sea water inlet grating

12.3.4.1 The grating of sea chest are to be connected by hinges or equivalent means, so as to facilitate the examination of internal conditions of the sea chest.

CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS

Section 1 GENERAL REQUIREMENTS FOR POLAR CLASS SHIPS

13.1.1 Application

13.1.1.1 This Chapter for Polar Class applies to ships constructed of steel and intended for independent navigation in ice-infested polar waters.

13.1.1.2 Ships that comply with the requirements of Sections 2 and 3 of this Chapter can be considered for a Polar Class notation “PC x” (where x is the corresponding class number) as listed in Table 13.1.2.1. The requirements of Sections 2 and 3 are in addition to the open water requirements. If the hull and machinery are constructed such as to comply with the requirements of different polar classes, then both the hull and machinery are to be assigned the lower of these classes in the classification certificate. Compliance of the hull or machinery with the requirements of a higher Polar Class is also to be indicated in the classification certificate or the equivalent.

13.1.1.3 Ships which are assigned a Polar Class notation and complying with the relevant requirements of Sections 2 and 3 of this Chapter may be given the additional notation “Icebreaker”. “Icebreaker" refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, and having a class certificate endorsed with this notation.

13.1.1.4 For ships which are assigned a Polar Class notation, the hull form and propulsion power are to be such that the ship can operate independently and at continuous speed in a representative ice condition, as defined in Table 13.1.2.1 for the corresponding Polar Class. For ships and ship-shaped units which are intentionally not designed to operate independently in ice, such operational intent or limitations are to be explicitly stated in the classification certificate or the equivalent.

13.1.1.5 For ships which are assigned a Polar Class notation PC 1 through PC 5, bows with vertical sides, and bulbous bows are generally to be avoided. Bow angles should in general be within the range specified in 13.2.3.1(5).

13.1.1.6 For ships which are assigned a Polar Class notation PC 6 and PC 7, and are designed with a bow with vertical sides or bulbous bows, operational limitations (restricted from intentional ramming) in design conditions are to be stated in the classification certificate or the equivalent.

13.1.2 Polar class

13.1.2.1 The Polar Class (PC) notations and descriptions are given in Table 13.1.2.1. It is the responsibility of the owner to select an appropriate Polar Class. The descriptions in Table 13.1.2.1 are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the ship with its intended voyage or service.

Polar Class Description **Table 13.1.2.1**

Polar Class	Ice Description (based on WMO Sea Ice Nomenclature)
PC1	Year-round operation in all polar waters
PC2	Year-round operation in moderate multi-year ice conditions
PC3	Year-round operation in second-year ice which may include multi-year ice inclusions
PC4	Year-round operation in thick first-year ice which may include old ice inclusions
PC5	Year-round operation in medium first-year ice which may include old ice inclusions
PC6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

13.1.2.2 The Polar Class notation is used throughout this Chapter for Polar Class ships to convey the differences between classes with respect to operational capability and structural strength.

13.1.3 Upper and lower ice waterlines

13.1.3.1 The upper and lower ice waterlines upon which the design of the vessel has been based are to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

13.1.3.2 The lower ice waterline (LIWL) is to be determined with due regard to the ship's ice-going capability in the ballast loading conditions. The propeller is to be fully submerged at the lower ice waterline(LIWL).

13.1.3.3 When the upper ice waterline (UIWL) is lower than the summer fresh water loadline draught, an ice class draught mark is to be provided in accordance with the requirements of 4.2.1.4, Section 2, Chapter 4, PART TWO of the Rules.

Section 2 STRUCTURAL REQUIREMENTS

13.2.1 Application and definitions

13.2.1.1 This Section applies to Polar Class ships as specified in Section 1 of this Chapter.

13.2.1.2 The length L_{UI} is the distance, in m, measured horizontally from the fore side of thestem at the intersection with the upper ice waterline (UIWL) to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L_{UI} is not to be less than 96%, and need not be greater than 97%, of the extreme length of the upper ice waterline (UIWL) measured horizontally from the fore side of the stem. In ships with unusual stern and bow arrangement the length L_{UI} will be specially considered.

13.2.1.3 The ship displacement D_{UI} is the displacement, in kt, of the ship corresponding to the upper ice waterline (UIWL). Where multiple waterlines are used for determining the UIWL, the displacement is to be determined from the waterline corresponding to the greatest displacement.

13.2.2 Hull areas

13.2.2.1 The hull of all Polar Class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: bow, bow intermediate, midbody and stern. The bow intermediate, midbody and stern regions are further divided vertically into the bottom, lower and ice belt regions. The extent of each hull area is illustrated in Figure 13.2.2.1.

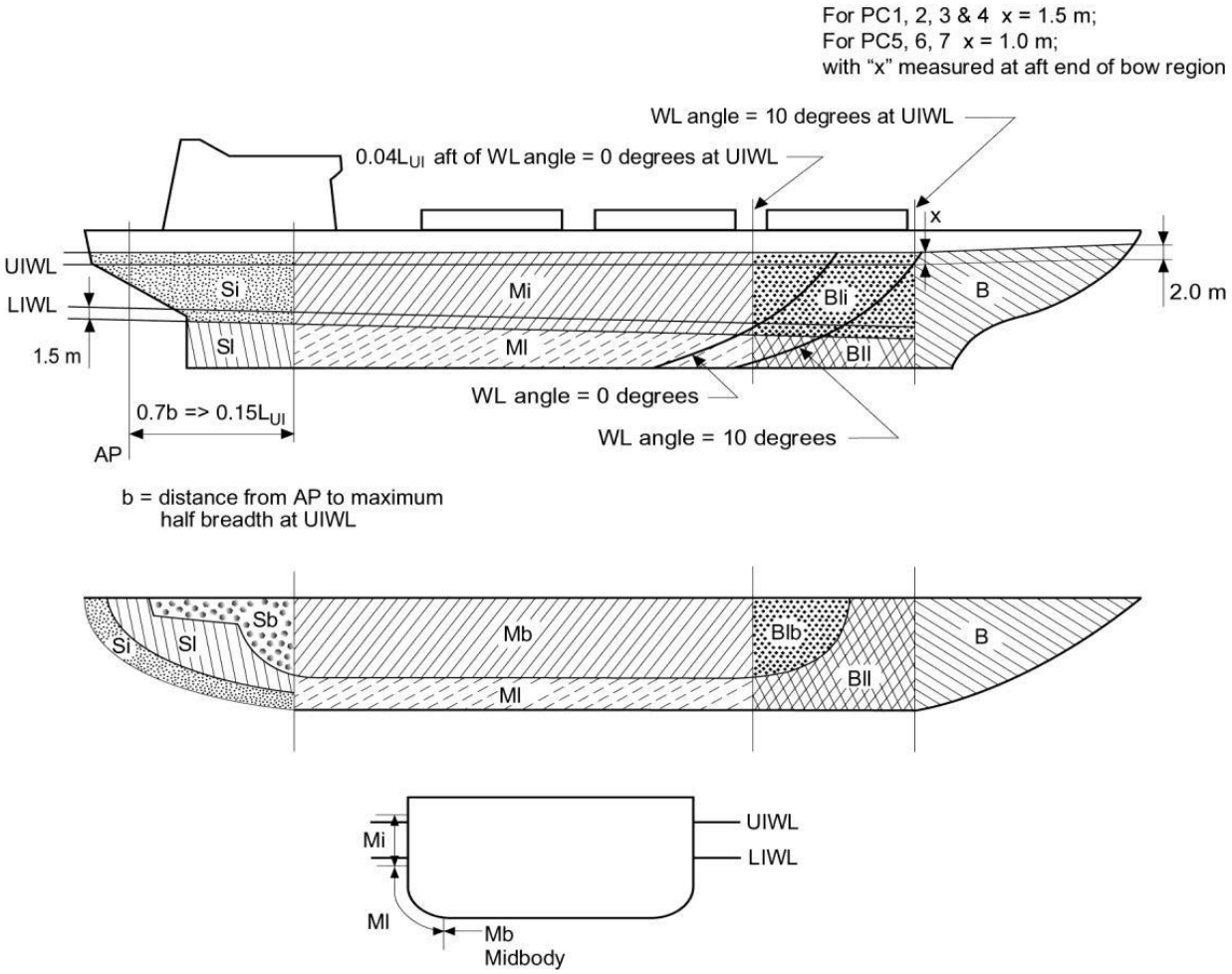


Figure 13.2.2.1 Extent of Hull Areas

13.2.2.2 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in 13.1.3.
13.2.2.3 Figure 13.2.2.1 notwithstanding, at no time is the boundary between the bow and bow intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.
13.2.2.4 Figure 13.2.2.1 notwithstanding, the aft boundary of the bow region need not be more than 0.45 L_{UI} aft of the fore side of the stem at the intersection with the upper ice waterline (UIWL).
13.2.2.5 The boundary between the bottom and lower regions is to be taken at the point where the shell is inclined 7° from horizontal.
13.2.2.6 If a ship is intended to operate astern in ice regions, the aft section of the ship is to be designed using the bow and bow intermediate hull area requirements.
13.2.2.7 Figure 13.2.2.1 notwithstanding, for ships assigned the additional notation "Icebreaker", the forward boundary of the stern region is to be at least 0.04L_{UI} forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

13.2.3 Design ice loads

13.2.3.1 General
(1) For all Polar Class ships, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.
(2) The design ice load is characterized by an average pressure (P_{avg}) uniformly distributed over a rectangular load patch of height (b) and width (w).
(3) Within the bow area of all Polar Class ships, and within the bow intermediate ice belt area of Polar Class PC6 and PC7, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters (P_{avg}, b and w), it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient (fa_i), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).
(4) In other ice-strengthened areas, the ice load parameters (P_{avg}, b_{NonBow} and w_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio, AR = 3.6.
(5) Design ice forces calculated according to 13.2.3.2(1)③ are applicable for bow forms where the buttock angle γ at the stem is positive and less than 80°, and the normal frame angle β' at the centre of the foremost sub-region, as defined in 13.2.3.2 (1)①, is greater than 10°.
(6) Design ice forces calculated according to 13.2.3.2(1)④ are applicable for ships which are assigned the Polar Class PC6 or PC7 and have a bow form with vertical sides. This includes bows where the normal frame angles β' at the considered sub-regions, as defined in 13.2.3.2(1)①, are between 0° and 10°.
(7) For ships which are assigned the Polar Class PC6 or PC7, and equipped with bulbous bows, the design ice forces on the bow are to be determined according to 13.2.3.2(1)④. In addition, the design forces are not to be taken less than those given in 13.2.3.2(1)③, assuming fa = 0.6 and AR = 1.3.
(8) For ships with bow forms other than those defined in (5) to (7), design forces are to be specially considered by ISC.
(9) Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, as referred to acceleration calculation in 13.3.6 of Section 3, are to be considered in the design of these structures.
13.2.3.2 Glancing impact load characteristics
The parameters defining the glancing impact load characteristics are reflected in the class factors listed in Tables 13.2.3.2(1) and 13.2.3.2(2).

Class Factors To Be Used in 13.2.3.2(1)③ **Table 13.2.3.2(1)**

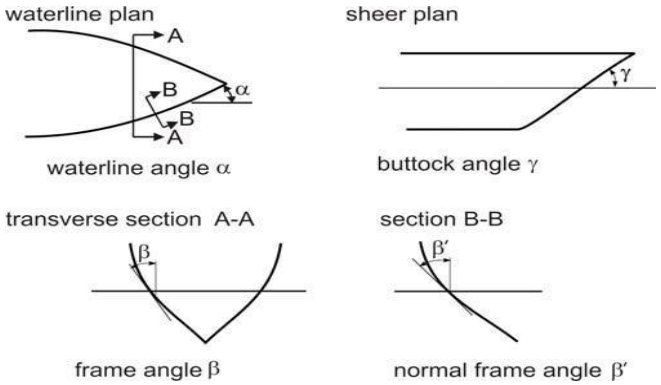
Polar Class	Crushing failure class factor (CF_C)	Flexural failure class factor (CF_F)	Load patch dimensions class factor (CF_D)	Displacement class factor (CF_{DIS})	Longitudinal strength class factor (CF_L)
PC1	17.69	68.60	2.01	250	7.46
PC2	9.89	46.80	1.75	210	5.46
PC3	6.06	21.17	1.53	180	4.17
PC4	4.50	13.48	1.42	130	3.15
PC5	3.10	9.00	1.31	70	2.50
PC6	2.40	5.49	1.17	40	2.37
PC7	1.80	4.06	1.11	22	1.81

Class Factors To Be Used in 13.2.3.2(1)④ **Table 13.2.3.2(2)**

Polar Class	Crushing failure class factor (CF_{CV})	Line load class factor (CF_{QV})	Pressure class factor (CF_{PV})
PC6	3.43	2.82	0.65
PC7	2.60	2.33	0.65

(1) Bow area

① In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient (fa). The hull angles are defined in Figure 13.2.3.2.



Notes: β' — normal frame angle at upper ice waterline [°];
α — upper ice waterline angle [°];
γ — buttock angle at upper ice waterline (angle of buttock line measured from horizontal) [°];
$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$;
$\tan(\beta') = \tan(\beta)\cdot\cos(\alpha)$.

Figure 13.2.3.2 Definition of Hull Angles

② The waterline length of the bow region is generally to be divided into 4 sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated with respect to the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_{avg}, b and w).

③ The bow area load characteristics for bow forms defined in 13.2.3.1(5) are determined as follows:

(a) Shape coefficient, fa_i, is to be taken as:

$$fa_i = \min(fa_{i,1}, fa_{i,2}, fa_{i,3})$$

where:
$$fa_{i,1} = \frac{\left[0.097 - 0.68\left(\frac{x}{L_{UI}} - 0.15\right)^2\right]\alpha_i}{(\beta_i')^{0.5}};$$

$$fa_{i,2} = \frac{1.2CF_F}{[\sin(\beta_i')\cdot CF_C \cdot D_{UI}{}^{0.64}]};$$

$$fa_{i,3} = 0.60;$$

(b) Force, F:

$$F_i = fa_i \cdot CF_C \cdot D_{UI}{}^{0.64} \quad \text{MN}$$

(c) Load patch aspect ratio, AR:

$$AR_i = 7.46\sin(\beta_i') \geq 1.3$$

(d) Line load, Q:

$$Q_i = F_i^{0.61} \cdot CF_D / AR_i^{0.35} \quad \text{MN/m}$$

(e) Pressure, P:

$$P_i = F_i^{0.22} \cdot CF_D^2 \cdot AR_i^{0.3} \quad \text{MPa}$$

where: i — sub-region considered;
L_{UI} — length, in m, as defined in 13.2.1.2;

x — distance from the fore side of the stem at the intersection with the upper ice waterline (UIWL) to station under consideration, in m;
α — waterline angle [°], see Figure 13.2.3.2;
β' — normal frame angle [°], Figure 13.2.3.2;
D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 5 kt;
CF_C — crushing failure class factor from Table 13.2.3.2(1);
CF_F — flexural failure class factor from Table 13.2.3.2(1).
CF_D — load patch dimensions class factor from Table 13.2.3.2(1);

④ The bow area load characteristics for bow forms defined in 13.2.3.1(6) are determined as follows:

(a) Shape coefficient, fa_i, is to be taken as:

$$fa_i=\alpha_i/30$$

(b) Force, F_i:

$$F_i = fa_i \cdot CF_{CV} \cdot D_{UI}^{0.47} \quad \text{[MN]}$$

(c) Line load, Q_i:

$$Q_i=F_i^{0.22}\cdot CF_{QV} \quad \text{[MN/m]}$$

(d) Pressure, P_i:

$$P_i=F_i^{0.56}\cdot CF_{PV} \quad \text{[MPa]}$$

where: i — sub-region considered;
α — waterline angle [°], see Figure 13.2.3.2;
β' — normal frame angle [°], Figure 13.2.3.2;
D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 5 kt;
CF_{CV} — crushing failure class factor from Table 13.2.3.2(2);
CF_{QV} — line load class factor from Table 13.2.3.2(2).
CF_{PV} — pressure class factor from Table 13.2.3.2(2);

(2) Hull areas other than the bow

① In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow}, w_{NonBow}) and design pressure (P_{avg}) are calculated as follows:

(a) Force, F_{NonBow}:

$$F_{\text{NonBow}}=0.36CF_C\cdot DF \quad \text{MN}$$

(b) Line load, Q_{NonBow}:

$$Q_{\text{NonBow}} = 0.639(F_{\text{NonBow}})^{0.61}\cdot CF_D \quad \text{MN/m}$$

where: CF_C — crushing force class factor from Table 13.2.3.2(1);
DF — ship displacement factor, taken as follows:

$$D_{UI}^{0.64} \quad \text{if } D_{UI} \le CF_{DIS}$$

$$CF_{DIS}^{0.64} + 0.10(D_{UI} - CF_{DIS}) \quad \text{if } D_{UI} > CF_{DIS}$$

D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 10 kt;
CF_{DIS} — displacement class factor from Table 13.2.3.2(1);
CF_D — load patch dimensions class factor from Table 13.2.3.2(1).

13.2.3.3 Design load patch

(1) In the bow area, and the ice belt area of intermediate bow for ships with class notation PC6 and PC7, the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$$w_{\text{Bow}} = F_{\text{Bow}} / Q_{\text{Bow}} \quad \text{m}$$
$$b_{\text{Bow}} = Q_{\text{Bow}} / P_{\text{Bow}} \quad \text{m}$$

where: F_{Bow} — maximum F_i in the bow area, in MN;
Q_{Bow} — maximum Q_i in the bow area, in MN/m;
P_{Bow} — maximum P_i in the bow area, in MPa.

(2) In hull areas other than those covered by 13.2.3.3(1), the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$$w_{NonBow}=F_{NonBow}/Q_{NonBow} \quad \text{m}$$

$$b_{NonBow} = w_{NonBow}/3.6 \qquad \text{m}$$

where: F_{NonBow} — force determined using 13.2.3.2(2)①(a), in MN;

Q_{NonBow} — line load determined using 13.2.3.2(2)①(b), in MN/m.

13.2.3.4 Pressure within the design load patch

(1) The average pressure, P_{avg}, within a design load patch is determined as follows:

$$P_{avg} = F/(b \cdot w) \qquad \text{MPa}$$

where: F — F_{Bow} or F_{NonBow} as appropriate for the hull area under consideration, in MN;

b — b_{Bow} or b_{NonBow} as appropriate for the hull area under consideration, in m;

w — w_{Bow} or w_{NonBow} as appropriate for the hull area under consideration, in m.

(2) Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in Table 13.2.3.4 are used to account for the pressure concentration on localized structural members.

Peak Pressure Factors **Table 13.2.3.4**

Structural member		Peak pressure factor (PPF_i)
Plating	Transversely-framed	$PPF_p = (1.8 - s) \geq 1.2$
	Longitudinally-framed	$PPF_p = (2.2 - 1.2\ s) \geq 1.5$
Frames in transverse framing systems	With load distributing stringers	$PPF_t = (1.6 - s) \geq 1.0$
	With no load distributing stringers	$PPF_t = (1.8 - s) \geq 1.2$
Frames in bottom structures		$PPF_s = 1.0$
Load carrying stringers Side longitudinals Web frames		$PPF_s = 1.0$, if $S_w \geq 0.5w$ $PPF_s = 2.0 - 2.0\ S_w/w$, if $S_w < (0.5w)$

where: s — frame or longitudinal spacing, in m;

S_w — web frame spacing, in m;

w — ice load patch width, in m.

13.2.3.5 Hull area factors

(1) Associated with each hull area is an area factor that reflects the relative magnitude of the load expected in that area. The area factor (*AF*) for each hull area is listed in Table 13.2.3.5(1).

(2) In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

(3) Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing (geared and podded) thrusters are to have stern ice belt (S_i) and stern lower (S_l) hull area factors *AF* listed in Table 13.2.3.5(3).

(4) For ships assigned the additional notation "Icebreaker", the area factor (*AF*) for each hull area is listed in Table 13.2.3.5(4)-1. For propulsion arrangements with azimuthing (geared and podded) thrusters, the area factor (*AF*) for each hull area is listed in Table 13.2.3.5(4)-2.

Hull Area Factors **Table 13.2.3.5(1)**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (*S*)	Ice belt	S_i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S_l	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Notes: * — See 13.2.3.1（3）.

** — Indicates that strengthening for ice loads is not necessary.

Hull Area Factors **Table 13.2.3.5(3)**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (*S*)	Ice belt	S_i	0.90	0.85	0.80	0.75	0.65	0.55	0.50
	Lower	S_l	0.60	0.55	0.50	0.45	0.45	0.40	0.40
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Notes: * — See 13.2.3.5(1).

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-1**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (*S*)	Ice belt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_l	0.55	0.50	0.45	0.45	0.45	0.45	0.45
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-2**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (*S*)	Ice belt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_l	0.70	0.65	0.60	0.60	0.60	0.60	0.60
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

13.2.4 Shell plate requirements

13.2.4.1 The required minimum shell plate thickness, *t*, is given by:

$$t = t_{net} + t_s \quad \text{mm}$$

where: t_{net} — plate thickness required to resist ice loads according to 13.2.4.2, in mm;

t_s — corrosion and abrasion allowance according to 13.2.11, in mm.

13.2.4.2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing.

In the case of transversely-framed plating ($\Omega \geq 70°$), and all bottom plating, i.e. plating in hull areas B_{Ib}, M_b and S_b, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5}/[1+s/(2b)] \quad \text{mm}$$

In the case of longitudinally-framed plating ($\Omega \geq 20°$), when $b \geq s$, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5}/[1+s/(2l)] \quad \text{mm}$$

In the case of longitudinally-framed plating ($\Omega \leq 20°$), when $b < s$, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5} \cdot [2b/s - (b/s)^2]^{0.5}/[1+s/(2l)] \quad \text{mm}$$

In the case of obliquely-framed plating ($70° > \Omega > 20°$), linear interpolation is to be used.

where: Ω — smallest angle between the chord of the waterline and the line of the first level framing, [°], illustrated in Figure 13.2.4.2;

s — transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships, in m;

AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);

PPF_p — peak pressure factor from Table 13.2.3.4;

P_{avg} — average patch pressure according to 13.2.3.4, in MPa;

R_{eH} — yield stress of the material, in N/mm^2;

b — height of design load patch, in m, where b is to be taken not greater than (l – s/4) in the case of determination of the net thickness for transversely-framed plating;

l — distance between frame supports, in mm, i.e. equal to the frame span as given in 13.2.5.5, but not reduced for any fitted end brackets. When a load-distributing stringer is fitted, the length l need not be taken larger than the distance from the stringer to the most distant frame support.

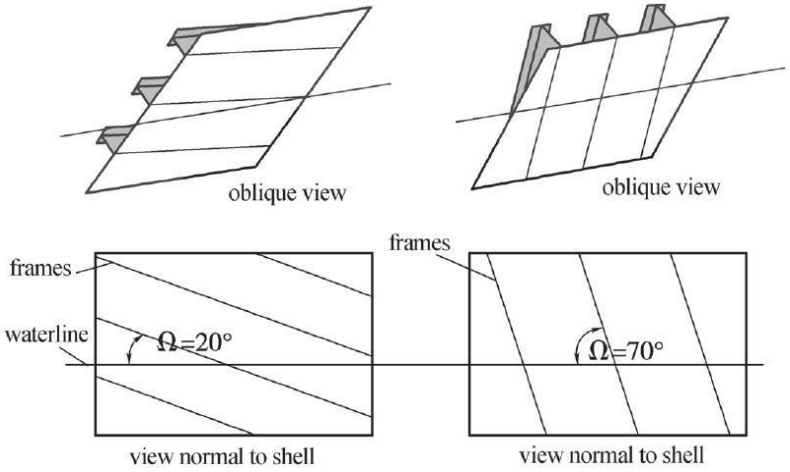


Figure 13.2.4.2 Shell Framing Angle Ω

13.2.5 Framing – General

13.2.5.1 Framing members of Polar Class ships are to be designed to withstand the ice loads defined in 13.2.3.

13.2.5.2 The term "framing member" refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, see Figure 13.2.2.1. Where load-distributing stringers have been fitted, they are generally fitted at or near the midpoint of the span of the frame, and web height of stringers is not to be less than 0.8 times the web height of the frame.

13.2.5.3 The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

13.2.5.4 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with the relevant requirements of Chapter 1, PART TWO of the Rules.

13.2.5.5 The effective span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the effective span may be reduced in accordance with the relevant requirements of Chapter 1, PART TWO of the Rules. Brackets are to be configured to ensure stability in the elastic and post-yield response regions.

13.2.5.6 When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.

13.2.5.7 The actual net effective shear area, A_w, of a transverse or longitudinal local frame is given by:

$$A_w = h\, t_{wn} \sin\varphi_w / 100 \qquad \text{cm}^2$$

where: h — height of stiffener, in mm, see Figure 13.2.5.7;

t_{wn} — net web thickness, in mm:

$t_{wn} = t_w - t_c$

where: t_w —as-built web thickness, in mm, see Figure 13.2.5.7;

t_c —corrosion deduction to be subtracted from the web and flange thickness, in mm, as specified in 13.2.11.3;

φ_w — smallest angle between shell plate and stiffener web, [°], measured at the midspan of the stiffener, see Figure 13.2.5.7. The angle φ_w may be taken as 90° provided the smallest angle is not less than 75°.

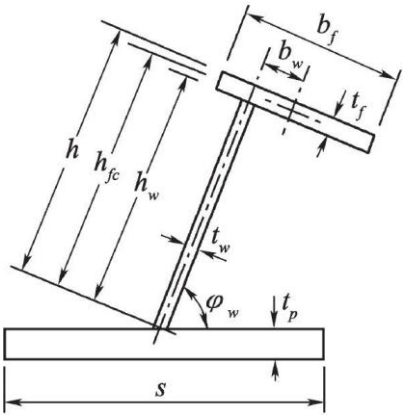


Figure 13.2.5.7 Stiffener Geometry

13.2.5.8 When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, of a transverse or longitudinal frame is given

$$Z_p = (A_{pn} t_{pn}/20) + \frac{h_w^2 t_{wn} \sin\varphi_w}{2000} + A_{fn}(h_{fc}\sin\varphi_w - b_w \cos\varphi_w)/10 \qquad \text{cm}^3$$

by:

where: h, t_{wn}, t_c and φ_w — as given in 13.2.5.7, s — as given in 13.2.4.2;

A_{pn} — net cross-sectional area of attached plate, in cm^2;

t_{pn} — net thickness of fitted shell plate, in mm (complying with t_{net} as required by 13.2.4.2);

h_w — height of local frame web, in mm, see Figure 13.2.5.7;

A_{fn} — net cross-sectional area of local frame flange, in cm^2;

h_{fc} — height of local frame measured to center of the flange area, in mm, see Figure 13.2.5.7;

b_w — distance from mid thickness plane of local frame web to the center of the flange area, in mm, see Figure 13.2.5.7.

When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$z_{na} = \left(100A_{fn} + h_w t_{wn} - 1000 t_{pn} s\right)/\left(2t_{wn}\right) \qquad \text{mm}$$

and the net effective plastic section modulus, Z_p, of a transverse or longitudinal frame is given by:

$$Z_p = t_{pn} \cdot s \cdot \left(z_{na} + \frac{t_{pn}}{2}\right)\sin\phi_w + \left\{ \begin{array}{l} \dfrac{[(h_w - z_{na})^2 + z_{na}^2]t_{wn}\sin\phi_w}{2000} \\ +A_{fn}[(h_{fc} - z_{na})\sin\phi_w - b_w\cos\phi_w]/10 \end{array} \right\} \qquad \text{cm}^3$$

13.2.5.9 In the case of oblique framing arrangement (70° > Ω > 20°, where Ω is defined as given in 13.2.4.2), linear interpolation is to be used.

13.2.6 Framing – Local frames in bottom structures and in transversely-framed side structures

13.2.6.1 The local frames in bottom structures (i.e. hull areas B_{lb}, M_b and S_b) and in transversely-framed side structures (i.e. hull areas B_{lb}, M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism. For bottom structure the patch load is to be applied with the dimension (b) parallel with the frame direction.

13.2.6.2 The actual net effective shear area of the frame, A_w, as defined in 13.2.5.7, is to comply with the following condition: $A_w \geq A_t$, where:

$$A_t = 100^2 \cdot 0.5LL \cdot s\left(AF \cdot PPF_t \cdot P_{avg}\right) / \left(0.577 R_{eH}\right) \qquad \text{cm}^2$$

where: LL — length of loaded portion of span, in m, to be taken as the lesser of a and b;
a — local frame span as defined in 13.2.5.5, in m;
b — height of design ice load patch according to 13.2.3.3(1) or (2), in m;
s — spacing of local frame, in m;
AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);
PPF_t — peak pressure factor, PPF_t or PPF_s as appropriate, from Table 13.2.3.4;
P_{avg} — average pressure within load patch according to 13.2.3.4, in MPa;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.6.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 13.2.5.8, is to comply with the following condition: $Z_p \geq Z_{pt}$, where Z_{pt} is to be the greater calculated on the basis of two load conditions: a) ice load acting at the midspan of the local frame, and b) the ice load acting near a support. The A_1 parameter in the equation below reflects the two conditions:

$$Z_{pt} = 100^3 \cdot LL \cdot Y \cdot s\left(AF \cdot PPF_t \cdot P_{avg}\right) a \cdot A_1 / \left(4 R_{eH}\right) \qquad \text{cm}^3$$

where: AF, PPF_t, P_{avg}, LL, s, a and R_{eH} — as given in 13.2.6.2;
Y = 1 − 0.5(LL/a);

$$A_{1A} = 1/\{1 + j/2 + (k_w j/2)\,[\,(1 - a_1^2)^{0.5} - 1]\}$$
$$A_{1B} = [1 - 1/(2a_1 \cdot Y)\,]/(0.275 + 1.44 k_z^{0.7})$$

A_1 — maximum of:
where:
j = 1 for a local frame with one simple support outside the ice-strengthened areas;
= 2 for a local frame without any simple supports;

$a_1 = A_t / A_w$

where:
A_t — minimum shear area of the local frame as given in 13.2.6.2, in cm^2;
A_w — effective net shear area of the local frame (calculated according to 13.2.5.7), in cm^2;

$k_w = 1/(1 + 2A_{fn}/A_w)$, with A_{fn} as given in 13.2.5.8;

k_z — z_p / Z_p, in general;
= 0.0, when the frame is arranged with end bracket;
where:

$$= (b_f \; t_{fn}^2/4 + b_{eff} \; t_{pn}^2/4)/1000$$

z_p — sum of individual plastic section moduli of flange and shell plate as fitted, cm^3;

where:
b_f — flange breadth, in mm, see Figure 13.2.5.7;
t_{fn} — net flange thickness, in mm, see Figure 13.2.5.7;
= $t_f - t_c$ (t_c as given in 13.2.5.7)
where:
t_f — as-built flange thickness, in mm, see Figure 13.2.5.7;
t_{pn} — the fitted net shell plate thickness, in mm, (not to be less than as t_{net} given in 13.2.4);
b_{eff} — effective width of shell plate flange, in mm:
= 500 s;

Z_p — net effective plastic section modulus of the local frame (calculated according to 13.2.5.8), in cm^3.

13.2.6.4 The scantlings of the local frame are to meet the structural stability requirements of 13.2.9.

13.2.7 Framing – Longitudinal local frames in side structures

13.2.7.1 Longitudinal local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

13.2.7.2 The actual net effective shear area of the frame, A_w, as defined in 13.2.5.7, is to comply with the following condition: $A_w \geq A_{L,}$ where:

$$A_L = 100^2 (AF \cdot PPF_s \cdot P_{avg}) 0.5 b_1 \cdot a / (0.577 R_{eH}) \quad \text{cm}^2$$

where: AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);
PPF_s — peak pressure factor from Table 13.2.3.4;
P_{avg} — average pressure within load patch according to13.2.3.4, in MPa;
b_1 $= k_0 b_2$, in m
where: $k_0 = 1 - 0.3/b'$;
where: $b' = b/s$
where: b — height of design ice load patch from 13.2.3.3 (1) or (2), in m;
s — spacing of longitudinal frames, in m;
$b_2 = b(1 - 0.25b')$, in m, if $b' < 2$;
$= s$, in m, if $b' \geq 2$;
a — effective span of longitudinal local frame as given in 13.2.5.5, in m;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.7.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 13.2.5.8, is to comply with the following condition: $Z_p \geq Z_{pL}$, where:

$$Z_{pL} = 100^3 (AF \cdot PPF_s \cdot P_{avg}) b_1 \cdot a^2 \cdot A_4 / (8 R_{eH}) \quad \text{cm}^3$$

where: AF, PPF_s, P_{avg}, b_1, a and R_{eH} — as given in 13.2.7.2;

$$A_4 = 1/\{2 + k_{wi}[(1 - a_4^2)^{0.5} - 1]\};$$

$$a_4 = A_L / A_w$$

where: A_L — minimum shear area for longitudinal, in cm^2, as given in 13.2.7.2;
A_w — net effective shear area of longitudinal (calculated according to 13.2.5.7), in cm^2;
$k_{wi} = 1/(1 + 2A_{fh}/A_w)$, with A_{fh} as given in 13.2.5.8.

13.2.7.4 The scantlings of the longitudinals are to meet the structural stability requirements of 13.2.9.

13.2.8 Framing – Web frame and load-carrying stringers

13.2.8.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 13.2.3. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized.

13.2.8.2 Web frames and load-carrying stringers are to be dimensioned such that the combined effects of shear and bending do not exceed the yield strength of the material. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor (*PPF*) from Table 13.2.4.3 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

13.2.8.3 For determination of scantlings of load carrying stringers, web frames supporting local frames, or web frames supporting load carrying stringers forming part of a structural grillage system, appropriate methods as outlined in 13.2.17 are normally to be used.

13.2.8.4 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 13.2.9.

13.2.9 Framing – Structural stability

13.2.9.1 To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_{wn}) of any framing member is not to exceed:

For flat bar sections: $h_w/t_{wn} \leq 282/(R_{eH})^{0.5}$

For bulb, tee and angle sections: $h_w/t_{wn} \leq 805/(R_{eH})^{0.5}$

where: h_w — web height;
t_{wn} — net web thickness;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.9.2 Framing members for which it is not practicable to meet the requirements of 13.2.9.1 (e.g. load carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2.63\times10^{-3} c_1\sqrt{R_{eH}/(5.34+4(c_1/c_2)^2)} \quad \text{mm}$$

where: c_1 $= h_w - 0.8h$, in mm;

where: h_w—web height of stringer / web frame, in mm, see Figure 13.2.9.2;

h — height of framing member penetrating the member under consideration (0 if no such framing member), in mm, see Figure 13.2.9.2;

c_2 — spacing between supporting structure oriented perpendicular to the member under consideration, in mm, see Figure 13.2.9.2;

R_{eH} — yield stress of the material, in N/mm^2.

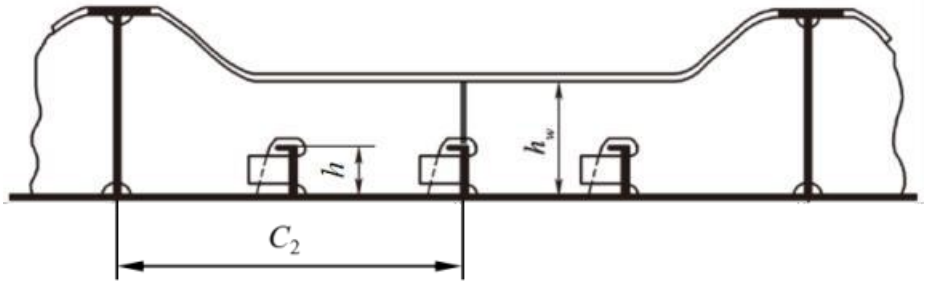


Figure 13.2.9.2 Parameter Definition for Web Stiffening

13.2.9.3 In addition, the following is to be satisfied:

$$t_{wn} \geq 0.35 t_{pn} (R_{eH}/235)^{0.5}$$

where: R_{eH} — yield stress of the shell plate in way of the framing member, in N/mm^2;

t_{wn} — net thickness of the web, in mm;

t_{pn} — net thickness of the shell plate in way the framing member, in mm.

13.2.9.4 To prevent local flange buckling of welded profiles, the following are to be satisfied:

(1) the flange width, b_f, in mm, is not to be less than five times the net thickness of the web, t_{wn};

(2) the flange outstand, b_{out}, in mm, is to meet the following requirement:

$$b_{out}/t_{fn} \leq 155/(R_{eH})^{0.5}$$

where: t_{fn}— net thickness of flange, in mm;

R_{eH} — yield stress of the material, in N/mm^2.

13.2.10 Plated Structures

13.2.10.1 Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

(1) web height of adjacent parallel web frame or stringer; or

(2) 2.5 times the depth of framing that intersects the plated structure.

13.2.10.2 The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

13.2.10.3 The stability of the plated structure is to adequately withstand the ice loads defined in 13.2.3.

13.2.11 Corrosion/abrasion additions and steel renewal

13.2.11.1 Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar Class ships.

13.2.11.2 The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each polar class are listed in Table 13.2.11.2.

Corrosion/Abrasion Additions for Shell Plating Table 13.2.11.2

Hull area	t_s (mm)					
	With effective protection			Without effective protection		
	PC1 to PC3	PC4 & PC5	PC6 & PC7	PC1 to PC3	PC4 & PC5	PC6 & PC7
Bow; bow intermediate ice belt	3.5	2.5	2.0	7.0	5.0	4.0
Bow intermediate lower; midbody & stern ice belt	2.5	2.0	2.0	5.0	4.0	3.0
Midbody & stern lower; bottom	2.0	2.0	2.0	4.0	3.0	2.5

13.2.11.3 Polar Class ships are to have a minimum corrosion/abrasion addition of t_s = 1.0 mm applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.
13.2.11.4 Steel renewal for ice strengthened structures is required when the gauged thickness is less than t_{net} + 0.5 mm.

13.2.12 Materials

13.2.12.1 Steel grades of plating for hull structures are to be not less than those given in Table 13.2.12.4 based on the as-built thickness, the Polar Class and the material class of structural members according to 13.2.12.2.

Material Classes for Structural Members **Table 13.2.12.1**

Structural Members	Material Class
Shell plating within the bow and bow intermediate ice belt hull areas (*B*, *BI*$_i$)	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in Table 1.3.2.2(1) of PART TWO of the Rules, structural members outside 0.4 L_{UI} amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the shell plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in Table 1.3.2.2(1) of PART TWO of the Rules, structural members within 0.2 L_{UI} from FP	II

13.2.12.2 Material classes specified in Table 1.3.2.2(1) of Section 3, Chapter 1 of PART TWO of the Rules are applicable to Polar Class ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating of Polar Class ships are given in Table 13.2.12.1. Where the material classes in Table 13.2.12.1 and those in Table 1.3.2.2(1) of Section 3, Chapter 1 of PART TWO of the Rules differ, the higher material class is to be applied.
13.2.12.3 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m below the lower waterline, as shown in Figure 13.2.12.3, are to be obtained from Table 1.3.2.2(6) and Table 1.3.2.2(7) of Section 3, Chapter 1 of PART TWO of the Rules based on the material class for structural members in Table 13.2.12.1 above, regardless of Polar Class.

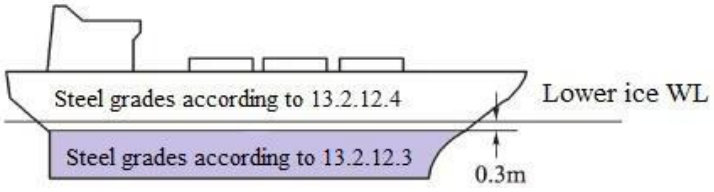


Figure 13.2.12.3
Steel Grade Requirements for Submerged and Weather Exposed Shell Plating

13.2.12.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m below the lower ice waterline (LIWL), as shown in Figure 13.2.12.3, are to be not less than that given in Table 13.2.12.4.

Steel Grades for Weather Exposed Plating **Table 13.2.12.4**

Thickness *t* [mm]	Material Class I				Material Class II				Material Class III					
	PC1 to PC5		PC6 & PC7		PC1 to PC 5		PC6 & PC 7		PC1 to PC 3		PC4 & PC 5		PC6 & PC 7	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
$10 < t \leq 15$	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$15 < t \leq 20$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$20 < t \leq 25$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$25 < t \leq 30$	D	DH	B	AH	E	EH(2)	D	DH	E	EH	E	EH	E	EH
$30 < t \leq 35$	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
$35 < t \leq 40$	D	DH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$40 < t \leq 45$	E	EH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH

45< t ≤50	E	EH	D	DH	E	EH	D	DH	F	FH	F	FH	E	EH

Notes:

(1) Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m below the lowest ice waterline.

(2) Grades D, DH are allowed for a single strake of side shell plating not more than 1.8 m wide from 0.3 m below the lowest ice waterline.

13.2.12.5 Castings are to have specified properties consistent with the expected service temperature for the cast component.

13.2.13 Longitudinal strength

13.2.13.1 Application

(1) A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull.

(2) Intentional ramming is not considered as a design scenario for ships which are designed with vertical or bulbous bows, see 13.1.1.6. Hence the longitudinal strength requirements given in 13.2.13 are not to be considered for ships with stem angle γ_{stem} equal to or larger than 80°.

(3) Ice loads are only to be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

13.2.13.2 Design vertical ice force at the bow

(1) The design vertical ice force at the bow, F_{IB}, is to be taken as:

$$F_{IB} = \min(F_{IB,1}, F_{IB,2}) \qquad \text{MN}$$

where: $F_{IB,1} = 0.534 K_I^{0.15} [\sin(\gamma_{stem})]^{0.2} (D_{UI} \cdot K_h)^{0.5} CF_L$ MN;

$F_{IB,2} = 1.20 CF_F$ MN;

where: K_I — indentation parameter, $= K_f / K_h$;

(a) for the case of a blunt bow form:

$$K_f = \left[2CB_{UI}^{1-e_b} / (1 + e_b) \right]^{0.9} \tan(\gamma_{stem})^{-0.9(1+e_b)}$$

(b) for the case of wedge bow form ($\alpha_{stem} < 80^\circ$), $e_b = 1$ and the above simplifies to:

$$K_f = \left\{ \tan(\alpha_{stem}) / [\tan(\gamma_{stem})]^2 \right\}^{0.9};$$

$K_h = 0.01 A_{wp}$ MN/m;

CF_L — longitudinal strength class factor from Table 13.2.3.2;

e_b — bow shape exponent which best describes the waterplane (see Figures 13.2.13.2(1) and 13.2.13.2(2))
= 1.0 for a simple wedge bow form
= 0.4 to 0.6 for a spoon bow form
= 0 for a landing craft bow form;
An approximate e_b determined by a simple fit is acceptable;

γ_{stem} — stem angle, [°], to be measured between the horizontal axis and the stem tangent at the upper ice waterline (UIWL) (buttock angle as per Figure 13.2.3.2 measured on the centerline);

α_{stem} — waterline angle measured in way of the stem at the upper ice waterline (UIWL) (°) (see Figure 13.2.3.2(1));

$$C = 1 / [2(L_B / B_{UI})^{e_b}]$$

where: B_{UI} — moulded breadth corresponding to the upper ice waterline (UIWL), in m;

L_B — bow length used in the equation $y = (B_{UI} / 2)(x / L_B)^{e_b}$, in m, (see Figures 13.2.13.2(1) and 13.2.13.2(2));

D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 10 kt;

A_{wp} — waterplane areacorresponding to the upper ice waterline (UIWL), in m^2;

CF_F — flexural failure class factor from Table 13.2.3.2(1).

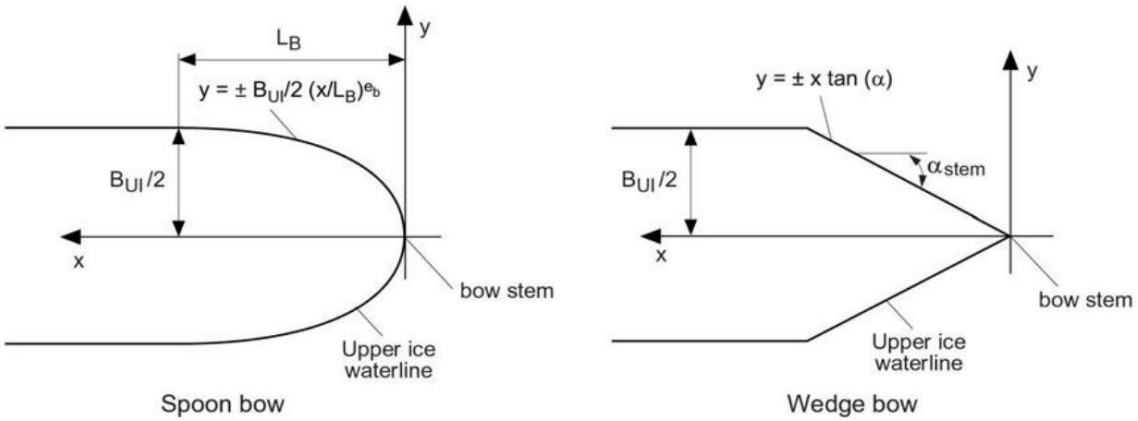


Figure 13.2.13.2(1) Bow Shape Definition

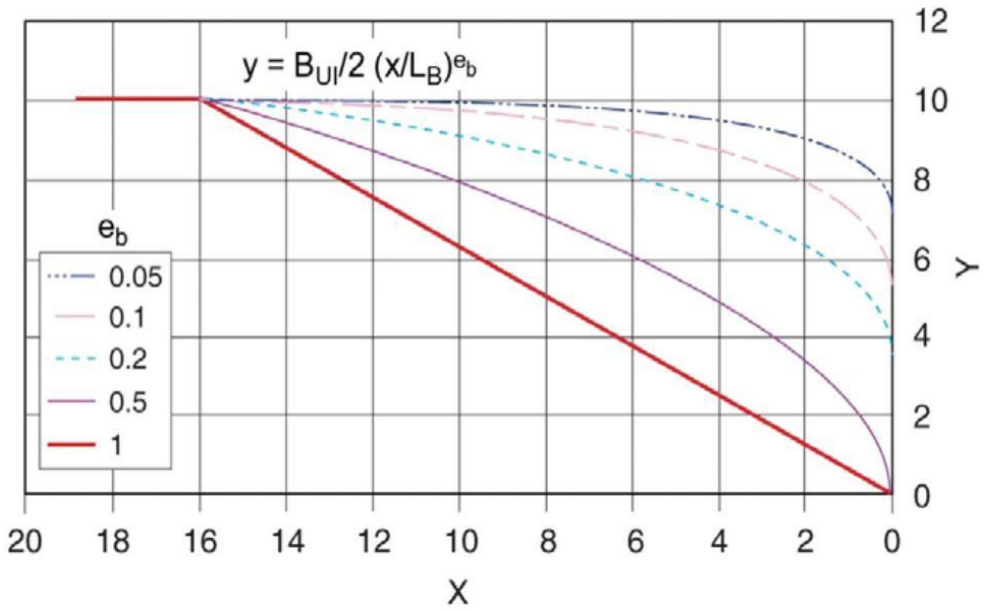


Figure 13.2.13.2 (2) Illustration of e_b Effect on the Bow Shape for B = 20 and L_B =16

13.2.13.3 Design vertical shear force

(1) The design vertical ice shear force, F_I, along the hull girder is to be taken as:

$$F_I = C_f F_{IB} \qquad \text{MN}$$

where: C_f — longitudinal distribution factor to be taken as follows:

(a) positive shear force

C_f = 0.0 between the aft end of L_{UI} and 0.6L_{UI} from aft;

C_f = 1.0 between 0.9L_{UI} from aft and the forward end of L_{UI};

(b) negative shear force

C_f = 0.0 at the aft end of L_{UI};

C_f = –0.5 between 0.2L_{UI} and 0.6L_{UI} from aft;

C_f = 0.0 between 0.8L_{UI} from aft and the forward end of L_{UI};

intermediate values are to be determined by linear interpolation.

(2) The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in 2.2.6 of Section 2, Chapter 2 of PART TWO of the Rules by substituting the design vertical ice shear force for the design vertical wave shear force.

13.2.13.4 Design vertical ice bending moment

(1) The design vertical ice bending moment, M_I, along the hull girder is to be taken as:

$$M_I = 0.1 C_m L_{UI} [\sin(\gamma_{stem})]^{-0.2} F_{IB} \qquad \text{MN·m}$$

where: L_{UI} — length, in m, as defined in 13.2.1.2;

γ_{stem} — as given in 13.2.13.2(1);

F_{IB} — design vertical ice force at the bow, in MN;

C_m — longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

C_m = 0.0 at the aft end of L_{UI};

C_m = 1.0 between $0.5L_{UI}$ and $0.7L_{UI}$ from aft;

C_m = 0.3 at $0.95L_{UI}$ from aft;

C_m = 0.0 at the forward end of L_{UI};

intermediate values are to be determined by linear interpolation.

(2) The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in 2.2.5 of Section 2, Chapter 2 of PART TWO of the Rules, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the permissible still water bending moment in sagging condition.

13.2.13.5 Longitudinal strength criteria

The strength criteria provided in Table 13.2.13.5 are to be satisfied. The design stress is not to exceed the permissible stress.

Longitudinal Strength Criteria **Table 13.2.13.5**

Failure mode	Applied stress	Permissible stress when $R_{eH}/\sigma_u \leq 0.7$	Permissible stress when $R_{eH}/\sigma_u > 0.7$
Tension	σ_a	ηR_{eH}	$0.41\eta\ (\sigma_u + R_{eH})$
Shear	τ_a	$\eta R_{eH} / (3)^{0.5}$	$0.41\eta\ (\sigma_u + R_{eH}) / (3)^{0.5}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners σ_c /1.1 for stiffeners	
	τ_a	τ_c	

Notes: σ_a — applied vertical bending stress, in N/mm^2;

τ_a— applied vertical shear stress, in N/mm^2;

R_{eH} — yield stress of the material, in N/mm^2;

σ_u— ultimate tensile strength of material, in N/mm^2;

σ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;

τ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;

η = 0.8;

η = 0.6 for ships which are assigned the additional notation “Icebreaker”.

13.2.14 Stem and stern frames

13.2.14.1 The stem and stern frame are to be designed according to the relevant requirements of Section 14, Chapter 2 of PART TWO of the Rules. For PC6/PC7 vessels requiring ISC ice class notations B1*/B1 equivalency, the stem and stern requirements of the ice class notations by Chapter 4, PART TWO of the Rules are to be complied with.

13.2.15 Appendages

13.2.15.1 All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

13.2.15.2 Load definition and response criteria are to be determined by practical situations.

13.2.16 Local details

13.2.16.1 For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to comply with the requirements of Chapter 1, PART TWO of the Rules.

13.2.16.2 The loads carried by a member in way of cut-outs are to maintain stability. Where necessary, the structure is to be stiffened.

13.2.17 Direct calculations

13.2.17.1 Direct calculations are not to be utilized as an alternative to the analytical procedures prescribed for the shell plating and local frame requirements given in 13.2.4, 13.2.6, and 13.2.7 of this Chapter.

13.2.17.2 Direct calculations are to be used for load carrying stringers and web frames forming part of a grillage system.

13.2.17.3 Where direct calculation is used to check the strength of structural systems, the load patch specified in 13.2.3 is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

13.2.17.4 The strength evaluation of web frames and stringers may be performed based on linear or non-linear analysis. Recognized structural idealization and calculation methods are to be applied, but the detailed requirements are to be specified by ISC. In the strength evaluation, the guidance given in 13.2.17.5 and 13.2.17.6 may generally be considered.

13.2.17.5 If the structure is evaluated based on linear calculation methods, the following are to be considered:

(1) web plates and flange elements in compression and shear to fulfil relevant buckling criteria as specified by ISC;

(2) nominal shear stresses in member web plates to be less than $R_{eH}/\sqrt{3}$;

(3) nominal von Mises stresses in member flanges to be less than $1.15\,R_{eH}$.

13.2.17.6 If the structure is evaluated based on non-linear calculation methods, the following are to be considered:

(1) the analysis is to reliably capture buckling and plastic deformation of the structure;

(2) the acceptance criteria are to ensure a suitable margin against fracture and major buckling and yielding causing significant loss of stiffness;

(3) permanent lateral and out-of plane deformation of considered member are to be minor relative to the relevant structural dimensions;

(4) detailed acceptance criteria to be decided by ISC.

13.2.18 Welding

13.2.18.1 All welding within ice-strengthened areas is to be of the double continuous type.

13.2.18.2 Continuity of strength is to be ensured at all structural connections.

Section 3 MACHINERY INSTALLATIONS

13.3.1 General requirements

13.3.1.1 The contents of this Section apply to main propulsion, steering gear, emergency and auxiliary systems essential for the safety of the ship and the crew.

13.3.1.2 Systems subject to damage by freezing, shall be drainable.

13.3.1.3 Vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient vessel operation in the case of propeller damage including the Controllable Pitch (CP) mechanism. Sufficient vessel operation means that the vessel should be able to reach safe haven (safe location) where repairs can be undertaken. This may be achieved either by a temporary repair at sea, or by towing, assuming assistance is available.

13.3.1.4 Means shall be provided to free a stuck propeller by turning it in reverse direction. This shall also be possible for a propulsion plant intended for unidirectional rotation.

13.3.1.5 The propeller shall be fully submerged at the ship's LIWL.

13.3.2 Drawings and particulars to be submitted

13.3.2.1 Details of the intended environmental operational conditions and the required ice strengthening for the machinery, if different from ship's ice class.

13.3.2.2 Detailed drawings and descriptions of the main propulsion, steering, emergency and auxiliary machinery and information on the essential main propulsion load control functions. The descriptions are to include operational limitations.

13.3.2.3 Description detailing where main, emergency and auxiliary systems are located and how they are protected to prevent problems from freezing, ice and snow accumulation and evidence of their capability to operate in the intended environmental conditions.

13.3.2.4 Calculations and documentation indicating compliance with the requirements of this Section.

13.3.3 Materials

13.3.3.1 Materials shall be of an approved ductile material. Ferritic nodular cast iron may be used for parts other than bolts. For nodular cast iron an averaged impact energy value of 10 J at testing temperature is regarded as equivalent to the Charpy V test requirements defined below.

13.3.3.2 Materials exposed to sea water

Materials exposed to sea water, such as propeller blades, propeller hubs and cast thruster bodies shall have an elongation not less than 15% on a test specimen according to ISC Rules for Materials and Welding.

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The

tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less than 20 J. However, Charpy V impact test requirements of ISC Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

13.3.3.3 Materials exposed to sea water temperature

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less than 20 J. However, the Charpy V impact test requirements of ISC Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

This requirement applies to components such as but not limited to blade bolts, CP mechanisms, shaft bolts, propeller shaft, strut-pod connecting bolts, etc. This requirement does not apply to surface hardened components, such as bearings and gear teeth or sea water cooling lines (heat exchangers, pipes, valves, fittings etc.).

For a definition of structural boundaries exposed to sea water temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.3.4 Material exposed to low air temperature

Materials of exposed machinery and foundations shall be manufactured from steel or other approved ductile material. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10 ºC below the lowest design temperature. Charpy V impact tests are not required for bronze and austenitic steel. This requirement does not apply to surface hardened components, such as bearings and gear teeth.

For a definition of structural boundaries exposed to air temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.4 Definition of main parameters and loads

13.3.4.1 The symbols, names, and units of parameters used in this Section are as follows:

c —— chord length of blade section, m;

$c_{0.7}$ —— chord length of blade section at 0.7R propeller radius, in m;

$c_{LE0.8}$ ——leading edge portion of chord length of blade section at 0.8R propeller radius, in m;

$c_{TE0.8}$ ——trailing edge portion of chord length of blade section at 0.8R propeller radius, in m;

D —— propeller diameter, in m;

d —— external diameter of propeller hub (at propeller plane), in m;

D_{pin} —— diameter of shear pin, in m;

D_{limit} —— limit value for propeller diameter, in m;

EAR —— expanded blade area ratio;

F_b —— maximum backward blade force for the ship's service life (negative sign), in kN;

F_{ex} —— ultimate blade load resulting from blade failure through plastic bending, abbreviated as blade failure load, in kN;

F_f —— maximum forward blade force for the ship's service life (positive sign), in kN;

F_{ice} —— ice load, in kN;

$(F_{ice})_{max}$—— maximum ice load for the ship's service life , in kN;

h_0 —— depth of the propeller centreline from lower ice waterline (LIWL), in m;

H_{ice} —— ice block dimension for propeller load definition, in m;

I —— equivalent mass moment of inertia of all parts on engine side of component under consideration , in kgm^2;

I_t —— equivalent mass moment of inertia of the whole propulsion system, in kgm^2;

$LIWL$ —— lower ice waterline, in m;

m —— slope for S-N curve in log/log scale;

M_{BL} —— blade bending moment, in kNm;

n —— propeller rotational speed, in r/s;

n_n —— nominal propeller rotational speed at MCR in free running condition, in r/s;

N —— number of ice load cycles;

N_{class} —— reference number of ice impacts per propeller revolution per ice class;

N_{ice} —— total number of ice load cycles on propeller blade for the ship's service life;

N_R —— reference number of ice load cycles for equivalent fatigue stress (10^8 cycles);

N_Q —— number of propeller revolutions during a milling sequence;

$P_{0.7}$ —— propeller pitch at 0.7R radius, in m;

$P_{0.7n}$ —— propeller pitch at 0.7R radius at MCR in free running condition, in m;

$P_{0.7b}$ —— propeller pitch at 0.7R radius at MCR in bollard condition, in m;

PCD —— pitch circle diameter, in m;

$Q(\varphi)$ —— torque, in kNm;

Q_{Amax} —— maximum response torque amplitude as a simulation result, in kNm;

Q_{emax} —— maximum engine torque, in kNm;

$Q_{F}(\varphi)$ —— Ice torque excitation for frequency domain calculations, in kNm;

Q_{fr} —— friction torque in pitching mechanism; reduction of spindle torque, in kNm;

Q_{max} —— maximum torque on the propeller resulting from propeller/ice interaction , in kNm;

Q_{motor} —— electric motor peak torque, in kNm;

Q_n —— nominal torque at MCR in free running condition, in kNm;

$Q_r(t)$ —— response torque along the propeller shaft line, in kNm;

Q_{peak} —— maximum of the response torque $Q_r(t)$, in kNm;

Q_{smax} —— maximum spindle torque of the blade for the ship's service life, in kNm;

Q_{sex} —— extreme spindle torque corresponding to the blade failure load F_{ex}, in kNm;

Q_{vib} —— Vibratory torque at considered component, taken from frequency domain open water TVC, in kNm;

r —— blade section radius, in m;

R —— propeller radius, in m;

$R_{p0.2}$ —— yield strength of the selected material (when the plastic strain is 0.2%), in MPa, to be selected according to ISC Rules for Materials and Welding;

R_m —— tensile strength of blade material, in MPa, to be selected according to ISC Rules for Materials and Welding;

S —— safety factor;

S_{fat} —— Safety factor for fatigue;

S_{ice} —— Ice strength index for blade ice force;

T —— Hydrodynamic propeller thrust in bollard condition, in kN;

T_b —— maximum backward propeller ice thrust for the ship's service life, in kN;

T_f —— maximum forward propeller ice thrust for the ship's service life, in kN;

T_n —— propeller thrust at MCR in free running condition, in kN;

T_r —— maximum response thrust along the shaft line, in kN;

T_{kmax} —— maximum torque capacity of flexible coupling, in kNm;

T_{kmax2} —— T_{kmax} at N= 1 load cycle, in kNm;

T_{kmax1} —— T_{kmax} at N= 5×10^4 load cycles, in kNm;

T_{kv} —— vibratory torque amplitude at N= 10^6 load cycles, in kNm;

ΔT_{kmax} —— maximum range of T_{kmax} at N=5×10^4 load cycles, in kNm;

t —— maximum blade section thickness, in m;

Z —— number of propeller blades;

z_{pin} —— number of shear pins;

α_i —— duration of propeller blade/ice interaction expressed in rotation angle, in ° ;

α_1 —— phase angle of the blade order excitation component for the propeller ice torque, in ° ;

α_2 —— phase angle of the blade order excitation component for the propeller ice torque, in ° ;

γ_ε —— the reduction factor for fatigue; scatter and test specimen size effect;

γ_v —— the reduction factor for fatigue; variable amplitude loading effect;

γ_m —— the reduction factor for fatigue; mean stress effect;

ρ —— a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles;

σ_{exp} —— mean fatigue strength of blade material at 10^8 cycles to failure in sea water, in MPa;

σ_{fat} —— equivalent fatigue ice load stress amplitude for 10^8 stress cycles, in MPa;

σ_{fl} —— characteristic fatigue strength for blade material, in MPa;

σ_{ref1} —— reference stress, $\sigma_{ref1} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, in MPa;

σ_{ref2} —— reference stress, $\sigma_{ref2} = 0.7 \cdot R_m$ or $\sigma_{ref2} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, whichever is less, in MPa;

σ_{st} —— maximum stress resulting from F_b or F_f, in MPa;

$(\sigma_{ice})_{bmax}$—— principal stress caused by the maximum backward propeller ice load, in MPa;

$(\sigma_{ice})_{fmax}$—— principal stress caused by the maximum forward propeller ice load, in MPa;

$(\sigma_{ice})_{Amax}$—— maximum ice load stress amplitude at the considered location on the blade, in MPa;

σ_{mean} —— mean stress, in MPa;

$(\sigma_{ice})_A(N)$—— blade stress amplitude distribution, in MPa.

13.3.4.2 The definition and use of loads used in this Section are given in Table 13.3.4.2:

Definition and use of loads **Table 13.3.4.2**

Load	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line. Ice contact pressure at leading edge is shown with small arrows. See Figure 13.3.4.2.	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.

Load	Definition	Use of the load in design process
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque Q_r along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8R.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components.
Q_{sex}	Maximum spindle torque resulting from blade failure load	Is used to ensure pyramid strength principle for the pitching mechanism
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller.	Design thrust for propeller shaft line components.

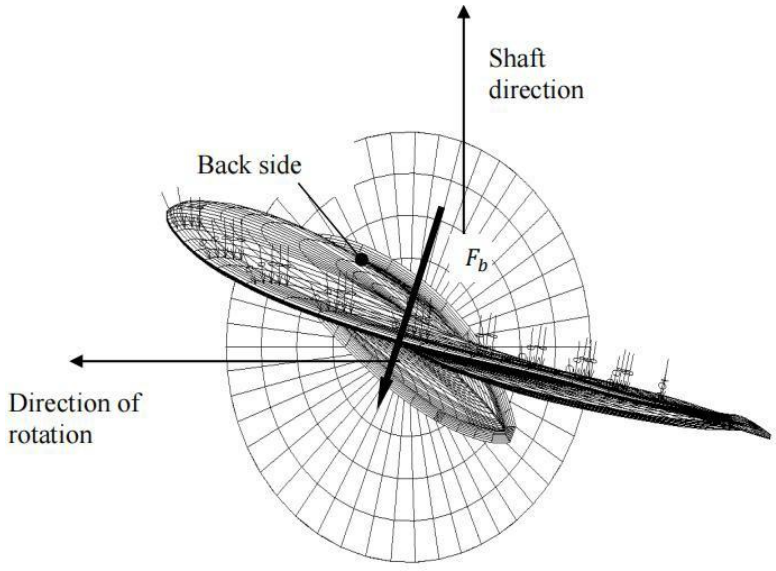


Figure 13.3.4.2 Direction of the backward blade force

13.3.5 Ice interaction loads

13.3.5.1 Propeller/ice interaction

These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow-mounted propellers shall receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ship's service life for normal operational conditions, including loads resulting from directional change of rotation where applicable. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules also cover loads due to propeller ice interaction for azimuthing and fixed thrusters with geared transmission or an integrated electric motor ("geared and podded propulsors"). However, the load models of the regulations do not include propeller/ice interaction loads when ice enters

the propeller of a turned azimuthing thruster from the side (radially) or loads when ice blocks hit on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters shall be estimated on a case by case basis, however are not included within the following section.
The loads given in section 13.3.5 are total loads including ice-induced loads and hydrodynamic loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.
F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.
F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead.

13.3.5.2 Ice class factors

The dimensions of the considered design ice block are $H_{ice} \times 2H_{ice} \times 3H_{ice}$. The design ice block H_{ice} and ice strength index S_{ice} used for the estimation of propeller ice loads are defined for each Ice class in Table 13.3.5.2 below.

Design ice block and ice strength index **Table 13.3.5.2**

Ice class	H_{ice}[m]	S_{ice}[−]
PC1	4.0	1.2
PC2	3.5	1.1
PC3	3.0	1.1
PC4	2.5	1.1
PC5	2.0	1.1
PC6	1.75	1
PC7	1.5	1

13.3.5.3 Design ice loads for open propellers

(1) Maximum backward blade force F_b

when $D<D_{limit}$:

$$F_b = -27 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_b = -23 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} H_{ice}^{1.4} D \qquad \text{kN}$$

where: $D_{limit} = 0.85 H_{ice}^{1.4}$;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n —— the nominal rotational speed at MCR in the free running open water condition for CP-propellers and 85% of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type), in r/s.

For vessels with the additional notation Icebreaker, the above stated backward blade force F_b shall be multiplied by a factor of 1.1.

(2) Maximum forward blade force F_f

when $D<D_{limit}$:

$$F_f = 250 \frac{EAR}{Z} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}} \right) H_{ice} \frac{EAR}{Z} D \qquad \text{kN}$$

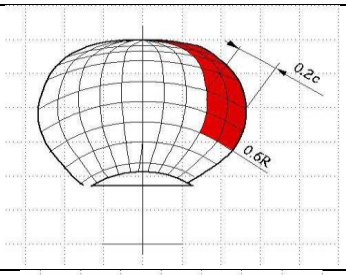
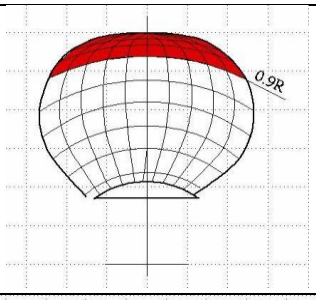
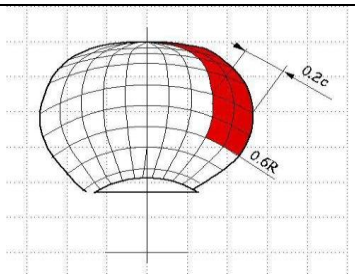
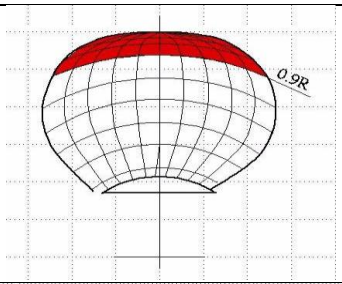
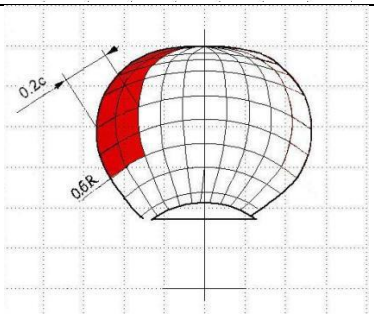
where: $D_{limit} = \left(\frac{2}{1 - \frac{d}{D}} \right) H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load cases

Load cases 1-4 shall be covered, as given in Table 13.3.5.3(3), for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers where reversing is possible.

Load cases for open propellers **Table 13.3.5.3(3)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50 % F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9*R* radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50%F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9*R* radius.	
Load case 5	60%F_f or 60%F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6*R* to the tip and from the trailing edge to 0.2 times the chord length	

13.3.5.4 Design ice loads for ducted propellers

(1) Maximum backward blade force F_b

when $D < D_{limit}$:

$$F_b = -9.5 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} D^2 \quad \text{kN}$$

when $D \geq D_{limit}$:

$$F_b = -66 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} H_{ice}^{1.4} D^{0.6} \quad \text{kN}$$

where: D_{limit} = 4 H_{ice}, in m;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n is the same as 13.3.5.3(1).

For vessels with the additional notation Icebreaker, the above stated backward blade force F_b shall be multiplied by a factor of 1.1.

(2) Maximum forward blade force F_f

when $D < D_{limit}$:

$$F_f = 250 \frac{EAR}{Z} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}} \right) H_{ice} \frac{EAR}{Z} D \qquad \text{kN}$$

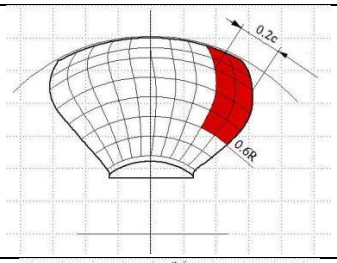
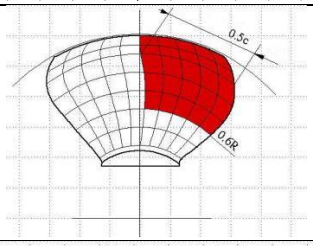
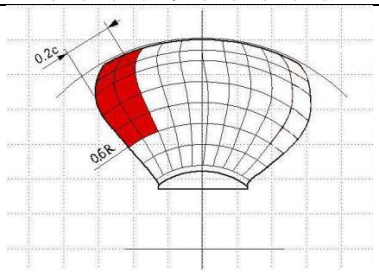
where: $D_{limit} = \left(\frac{2}{1 - \frac{d}{D}} \right) H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load case

Load cases 1 and 3 shall be covered as given in Table 13.3.5.4(3) for all propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers, where reversing is possible.

Load cases for ducted propellers **Table 13.3.5.4(3)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6*R* to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60%F_f or 60%F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6*R* to the tip and from the trailing edge to 0.2 times the chord length.	

13.3.5.5 Design ice loads for both open and ducted propellers

(1) Maximum blade spindle torque Q_{smax} for CP mechanism designing

The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as per Table 13.3.5.3(3) and Table 13.3.5.4(3). If the above method gives a value which is less than the default value given by the formula below, the default value shall be used.

$$Q_{smax} = 0.25Fc_{0.7} \qquad \text{kNm}$$

where: F is taken as either F_b or F_f, whichever has the greater absolute value.

The blade failure spindle torque Q_{sex} is defined under 13.3.5.6.

(2) Load distributions (spectra) for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Figure 13.3.5.5(2) is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geqslant \frac{F}{(F_{ice})_{\max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{\max}}\right)^{k} \ln(N_{ice})\right)}$$

where: k —shape parameter of the spectrum, for open propeller, k=0.75; for ducted propeller, k=1.0;

N_{ice} —number of load cycles in the spectrum, see 13.3.5.5(3);

F_{ice} —random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

This results in a blade stress amplitude distribution:

$$(\sigma_{ice})_A(N) = (\sigma_{ice})_{A\max}\left\{1 - \frac{\log(N)}{\log(N_{ice})}\right\}^{\frac{1}{k}}$$

where: $(\sigma_{ice})_{A\max} = \dfrac{(\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max}}{2}$.

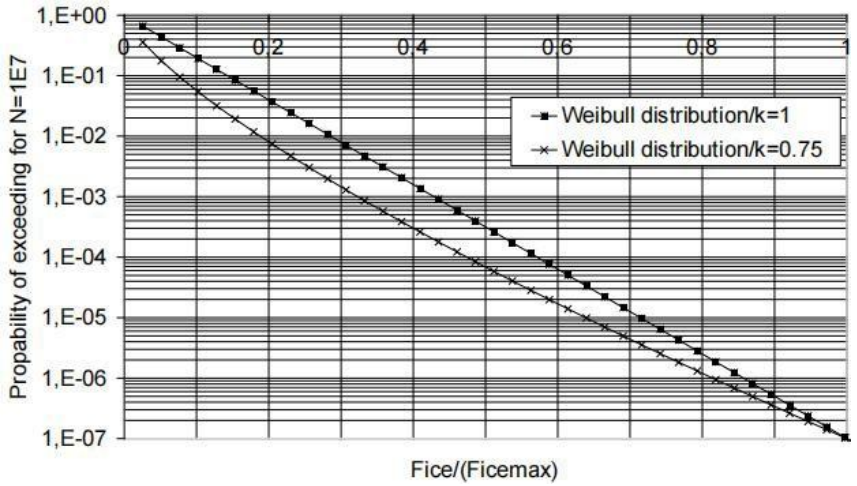


Figure 13.3.5.5(2) The Weibull-type distribution (probability of exceedance) that is used for fatigue design

(3) Number of ice loads

Number of load cycles in the load spectrum per blade is to be determined according to the formula:

$$N_{ice} = k_1 k_2 N_{class} n$$

where: N_{class} — reference number of impacts per propeller revolution for each ice class (Table 13.3.5.5(3));

k_1 — propeller position coefficient, to be taken as 1 for centre propeller; 2 for wing propeller; 3 for pulling propeller (wing and centre);

k_2 — immersion coefficient, to be determined as follows:

when $f < 0$, $k_2 = 0.8 - f$;

when $0 \leqslant f \leqslant 1$, $k_2 = 0.8 - 0.4f$;

when $1 < f \leqslant 2.5$, $k_2 = 0.6 - 0.2f$;

when $f > 2.5$, $k_2 = 0.1$;

where: $f = \dfrac{h_0 - H_{ice}}{D/2} - 1$, if h_0 is not known, h_0 may be taken as *D/2*.

k_3 — thruster type coefficient, to be taken as 1 for fixed thrusters and 1.2 for azimuthing thrusters;

For vessels with the additional notation Icebreaker, the above stated number of load cycles N_{ice} shall be multiplied by a factor of 3.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

Reference number of impacts **Table 13.3.5.5(3)**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
N_{class}	21×10^6	17×10^6	15×10^6	13×10^6	11×10^6	9×10^6	6×10^6

13.3.5.6 Blade failure load for both open and ducted Propellers

(1) Bending force F_{ex}

The minimum load required resulting in blade failure through plastic bending. This shall be calculated iteratively along the radius of the blade from blade root to 0.5*R* using the equation below with the ultimate load assumed to be acting at 0.8*R* in the weakest direction.

$$F_{ex} = \frac{0.3ct^2\sigma_{ref1}}{0.8D - 2r} \times 10^3 \qquad \text{kN}$$

where:c, t and r are respectively the actual chord length, maximum thickness and radius of the cylindrical root section of the blade, which is the weakest section outside the root fillet located typically at the termination of the fillet into the blade profile.

The failure load may be calculated alternatively by means of an appropriate stress analysis reflecting the non-linear plastic material behaviour of the actual blade. A blade is regarded as having failed, if the tip is bent by more than 10% of the propeller diameter.

(2) Spindle torque Q_{sex}

The maximum spindle torque due to a blade failure load acting at 0.8R shall be determined.

The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation the maximum spindle torque will occur. This maximum spindle torque shall be defined by an appropriate stress analysis or using equation below.

$$Q_{sex} = \max(c_{LE0.8}, 0.8c_{TE0.8}) C_{spex} F_{ex}$$

where: $C_{spex} = C_{sp} C_{fex} = 0.7\left[1 - \left(4\frac{EAR}{Z}\right)^3\right]$, to be taken not less than 0.3;

C_{sp} —non-dimensional parameter taking into account the spindle arm;

C_{fex} —non-dimensional parameter taking into account the reduction of blade failure force at the location of maximum spindle torque;

Figure 13.3.5.6(2) illustrates the spindle torque values due to blade failure loads across the whole chord length.

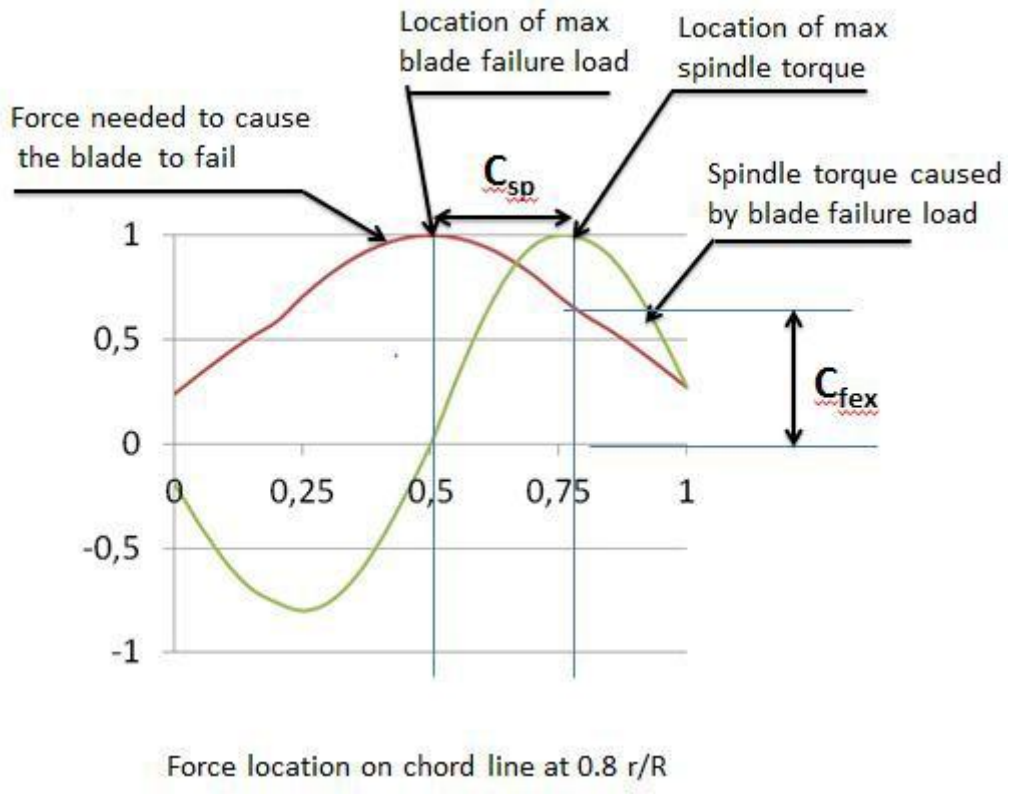


Figure 13.3.5.6(2) Schematic figure showing blade failure load and related spindle torque when the force acts at different location on the chord line at radius 0.8R

13.3.5.7 Axial design loads acting on open and ducted propellers

(1) Maximum ice thrust on propeller

Forward thrust T_f:

$$T_f = 1.1F_f \qquad \text{kN}$$

Backward thrust T_b:

$$T_b = 1.1F_b \qquad \text{kN}$$

However, the load models within this Section do not include propeller/ice interaction loads where an ice block hits the propeller hub of a pulling propeller.

(2) Design thrust along the propulsion shaft line for propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward directional load shall be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction:

$$T_r = T + 2.2T_f \qquad \text{kN}$$

In a backward direction:

$$T_r = 1.5T_b \qquad \text{kN}$$

If the hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Value of T **Table 13.3.5.7(2)**

Propeller type	***T***
CP propellers (open)	$1.25T_n$
CP propellers (ducted)	$1.1\ T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85\ T_n$
FP propellers driven by diesel engine (ducted)	$0.75\ T_n$

Note: T_n is the nominal propeller thrust at MCR in the free running open water condition, in kN.

For pulling type propellers ice interaction loads on propeller hub must be considered in addition to the above. These will be specially considered by ISC.

13.3.5.8 Torsional design loads acting on open and ducted propellers

(1) Design ice torque on propeller for open propellers

when $D < D_{limit}$:

$$Q_{\max} = k_{open}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kNm}$$

when $D \geq D_{limit}$:

$$Q_{\max} = 1.9k_{open}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \qquad \text{kNm}$$

where: $D_{limit} = 1.8\ H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{open} ——14.7 for PC1~PC5; 10.9 for PC6~PC7;

$P_{0.7}$ ——propeller pitch at 0.7R, in m; (For CP propellers, $P_{0.7}=P_{0.7b}$; if $P_{0.7b}$ is not known, $P_{0.7}=0.7P_{0.7n}$)

n —— the rotational propeller speed in r/s in bollard condition. If not known, n is to be taken as follows:

Value of *n* **Table 13.3.5.8(1)**

Propeller type	*n*
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propeller driven by diesel engine	$0.85n_n$

Note: n_n is the nominal propeller rotational speed at MCR in the free running open water condition, in r/s.

(2) Design ice torque on propeller for ducted propellers

when $D<D_{limit}$:

$$Q_{\max} = k_{ducted}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kNm}$$

when $D\geq D_{limit}$:

$$Q_{\max} = 1.9k_{ducted}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \qquad \text{kNm}$$

where: D_{limit} = 1.8 H_{ice}, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{ducted} ——10.4 for PC1~PC5; 7.7 for PC6~PC7;

$P_{0.7}$ and n are selected in accordance with 13.3.5.8(1).

(3) Ice torque excitation for open and ducted propellers

The given excitations are used to estimate the maximum torque likely to be experienced once during the service life of the ship. The following load cases are intended to reflect the operational loads on the propulsion system when the propeller interacts with ice and the corresponding reaction of the complete system. The ice impact and system response cause loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed a relevant Q_{max} may be calculated using the relevant speed.

Diesel engine plants without an elastic coupling shall be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in time domain. The engine firing pulses shall be included in the calculations and their standard steady state harmonics can be used. A phase angle between ice and gas force excitation does not need to be regarded in frequency domain analysis. Misfiring does not need to be considered.

If there is a blade order resonance just above MCR speed, calculations shall cover the rotational speeds up to 105% of MCR speed.

See also Guidelines for calculations given in 13.3.5.9

① Excitation for the time domain calculation

The propeller ice torque excitation for shaft line transient dynamic analysis (time domain) is defined as a sequence of blade impacts which are of half sine shape and occur at the blade.

The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined as:

when $\varphi = 0\ldots a_i$,

$$Q(\varphi) = C_q Q_{max} sin[\varphi(180/a_i)] \qquad \text{kNm}$$

when $\varphi = a_i\ldots 360$,

$$Q(\varphi) = 0 \qquad \text{kNm}$$

where: φ is rotation angle starting when the first impact occurs.

Parameters C_q and α_i for different blade numbers are given in Table 13.3.5.8(3)①.

Ice impact magnification C_q and duration α_i factors for different blade numbers

Table 13.3.5.8(3)①

Torque excitation	Propeller/ ice interaction	C_q	α_i (°)			
			Z=3	Z=4	Z=5	Z=6
Excitation case 1	Single ice block	0.75	90	90	72	60
Excitation case 2	Single ice block	1.0	135	135	135	135
Excitation case 3	Two ice blocks （phase shift=360°/(2Z)）	0.5	45	45	36	30
Excitation case 4	Single ice block	0.5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360°/Z.

At the beginning and at the end of the milling sequence (within calculated duration) linear ramp functions shall be used to increase C_q to its maximum within one propeller revolution and vice versa to decrease it to zero (see Figure 13.3.5.8(3)①).

The number of propeller revolutions during a milling sequence shall be obtained from the formula:

$$N_Q = 2H_{ice}$$

The number of impacts for blade order excitation:

$$ZN_Q$$

where: H_{ice} is selected in accordance with Table 13.3.4.2.

An illustration of all excitation cases for different blade numbers is given in Figure 13.3.5.8(3)①.

The dynamic simulation shall be performed for all excitation cases starting at MCR nominal, MCR bollard condition and just above all resonance speeds (1st engine and 1st blade harmonic), so that the resonant vibration responses can be obtained. For a fixed pitch propeller plant the dynamic simulation shall also cover bollard pull condition with a corresponding speed assuming maximum possible output of the engine. If a speed drop occurs down to stand still of the main engine, it indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process shall be applied. On these cases, the excitation shall follow the shaft speed.

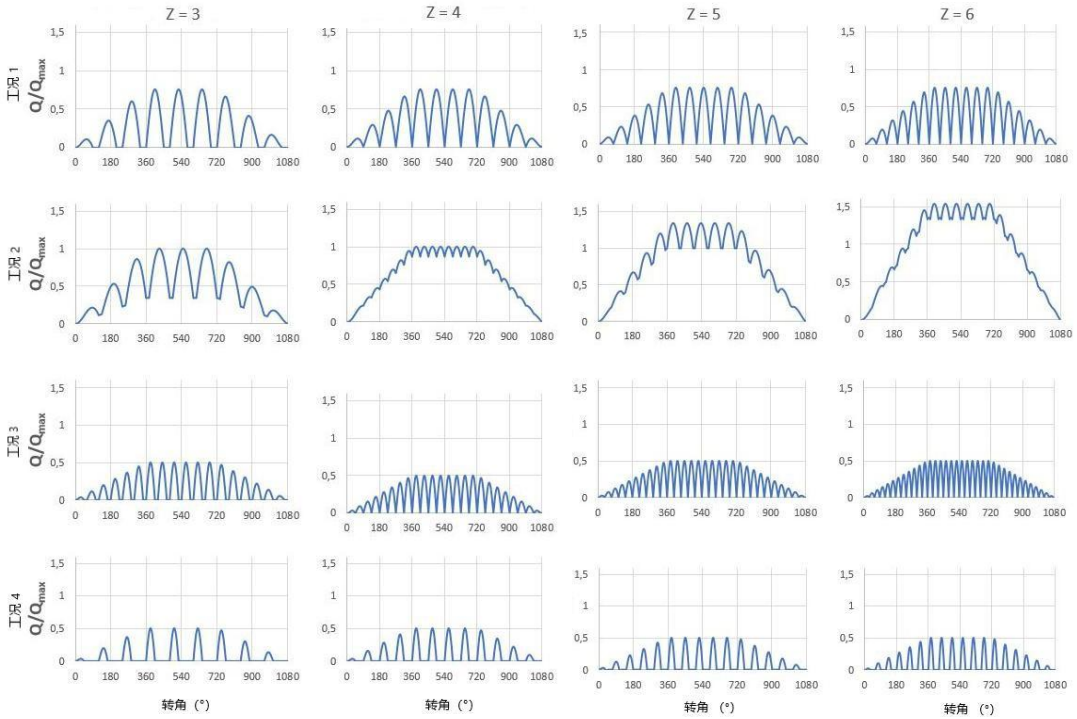


Figure 13.3.5.8(3)①　Ice block torque excitation cases for 3~6 blade propellers

② Frequency domain excitation

For frequency domain calculations the following torque excitation may be used. The excitation has been derived so that the time domain half sine impact sequences have been assumed to be continuous and the Fourier series components for blade order and twice the blade order components have been derived. The frequency domain analysis is generally considered as conservative compared to the time domain simulation provided there is a first blade order resonance in the considered speed range.

$$Q_F(\varphi) = Q_{\max} \cdot \left[C_{q0} + C_{q1} \cdot \sin\left(Z \cdot E_0 \cdot \varphi + \alpha_1\right) + C_{q2} \cdot \sin\left(2Z \cdot E_0 \cdot \varphi + \alpha_2\right) \right] \quad \text{kNm}$$

where: φ ——angle of rotation;

C_{q0} ——mean torque component;

C_{q1} ——first blade order excitation amplitude;

C_{q2} ——second blade order excitation amplitude;

E_0 ——Number of ice blocks simultaneously participating in the impact.

Coefficients for simplified excitation torque estimation are given in Table 13.3.5.8(3)②.

Coefficients for simplified excitation torque estimation **Table 13.3.5.8(3)②**

Torque excitation	Z=3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.375	0.375	-90	0	0	1
Case 2	0.7	0.33	-90	0.05	-45	1
Case 3	0.25	0.25	-90	0	0	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=4					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	0.9375	0	-90	0.0625	-90	1
Case 3	0.25	0.251	-90	0	0	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=5					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	1.19	0.17	-90	0.02	-90	1
Case 3	0.3	0.25	-90	0.048	-90	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=6					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.375	-90	0.05	-90	1
Case 2	1.435	0.1	-90	0	0	1
Case 3	0.3	0.25	-90	0.048	-90	2
Case 4	0.2	0.25	0	0.05	-90	1

Torsional vibration responses shall be calculated for all excitation cases.

The results of the relevant excitation cases at the most critical rotational speeds are to be used in the following way:

The highest response torque (between the various lumped masses in the system) is in the following referred to as peak torque Q_{peak}, see Figure 13.3.5.8(3)②.

The highest torque amplitude during a sequence of impacts is to be determined as half of the range from max to min torque and is referred to as Q_{Amax}, see Figure 13.3.5.8(3)②.

Q_{Amax} can by determined by:

$$Q_{\text{Amax}} = \left[\max(Q_r(t)) - \min(Q_r(t))\right] / 2 \quad \text{kNm}$$

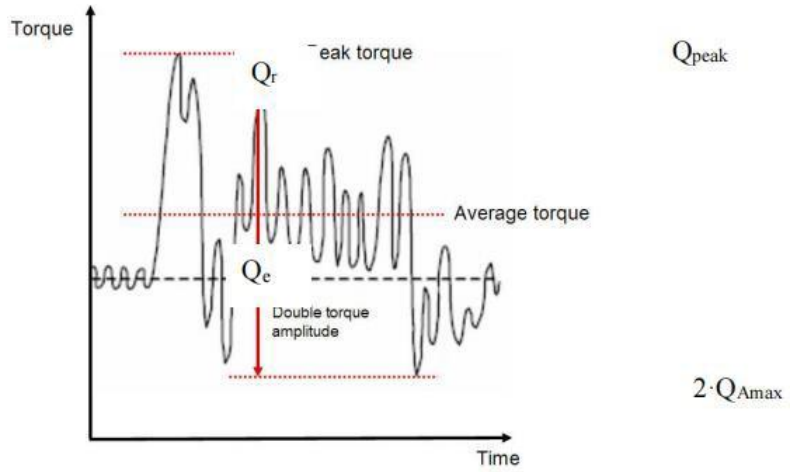


Figure 13.3.5.8(3)② Interpretation of different torques in a measured curve, as example

(4) Design torque along shaft line

① If there is no relevant first order propeller torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed in bollard condition, the following estimation of the maximum response torque can be used to calculate the design torque along the propeller shaft line.

$$Q_r = Q_{e\max} + Q_{vib} + Q_{\max}\frac{I}{I_t} \qquad \text{kNm}$$

$$Q_r = Q_{e\max} + Q_{\max}\frac{I}{I_t} \qquad \text{kNm}$$

The above equation is to be applied for directly coupled two stroke Diesel engines without flexible coupling. For all other plants:

where: all the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque Q_{emax} is not known, it shall be taken as follows:

Value of Q_{emax} **Table 13.3.5.9(1)**

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Note: Q_{motor} is the electric motor peak torque.

② If there is a first blade order torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed (bollard condition), the design torque (Q_r) of the shaft component shall be determined by means of a dynamic torsional vibration analysis of the entire propulsion line in the time domain or alternatively in the frequency domain. It is then assumed that the plant is sufficiently designed to avoid harmful operation in barred speed range.

13.3.5.9 Torsional vibration calculation

(1) The aim of torsional vibration calculations is to estimate the torsional loads for individual shaft line components over the life time in order to determine scantlings for safe operation. The model can be taken from the normal lumped mass elastic torsional vibration model (frequency domain) including the damping. Standard harmonics may be used to consider the gas forces. The engine torque - speed curve of the actual plant shall be applied.

(2) For time domain analysis the model should include the ice excitation at propeller, the mean torques

provided by the prime mover and the hydrodynamic mean torque produced by the propeller as well as any other relevant excitations. The calculations should cover the variation of phase between the ice excitation and prime mover excitation. This is extremely relevant for propulsion lines with direct driven combustion engines.
(3) For frequency domain calculations the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load peaks. The first and second order blade components should be used for excitation. The calculation should cover the whole relevant shaft speed range. The analysis of the responses at the relevant torsional vibration resonances may be performed for open water (without ice excitation) and ice excitation separately. The resulting maximum torque can be obtained for directly coupled plants by the following superposition:

$$Q_{peak} = Q_{e\max} + Q_{opw} + Q_{ice} \qquad \text{kNm}$$

where: Q_{emax} ——the maximum engine torque at considered rotational speed;
Q_{opw} ——the maximum open water response of engine excitation at considered shaft speed and determined by frequency domain analysis;
Q_{ice} ——the calculated torque using frequency domain analysis for the relevant shaft speeds, ice excitation cases 1-4, resulting in the maximum response torque due to ice excitation.

13.3.6 Design

13.3.6.1 Design principle

The propulsion line shall be designed according to the pyramid strength principle in terms of its strength. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

The propulsion line components shall withstand maximum and fatigue operational loads with the relevant safety margin. The loads do not need to be considered for shaft alignment or other calculations of normal operational conditions.

13.3.6.2 Fatigue design in general

The design loads shall be based on the ice excitation and where necessary (shafting) dynamic analysis, described as a sequence of blade impacts (13.3.5.8(3)①). The shaft response torque shall be determined according 13.3.5.8(4).

The propulsion line components are to be designed so as to prevent accumulated fatigue failure when considering the relevant loads using the linear elastic Miner's rule as defined below.

$$D_{mds} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_k}{N_k} \le 1 \qquad \text{or} \qquad D_{mds} = \sum_{J=1}^{j=k} \frac{n_j}{N_j} \le 1$$

where: k —— the number of stress levels;
$N_{1\ldots k}$——the number of load cycles to failure of the individual stress level class;
$n_{1\ldots k}$——the accumulated number of load cycles of the case under consideration, per class;
D_{mds}——Miners damage sum.

The stress distribution should be divided into a frequency load spectrum having minimum 10 stress blocks (every 10 % of the load). Calculation with 5 stress blocks has been found to be too conservative. The maximum allowable load is limited by σ_{ref2} for propeller blades and yield strength for all other components. The load distribution (spectrum) should be in accordance with the Weibull distribution.

13.3.6.3 Propeller blades

(1) Calculation of blade stresses due to static loads

The blade stresses (equivalent and principal stresses) shall be calculated for the design loads given in 13.3.5.3 and 13.3.5.4. Finite element analysis (FEA) shall be used for stress analysis as part of the final approval for all propeller blades. The von Mises stresses, taken as σ_{st}, shall comply with criteria in (2).

Alternatively, the following simplified equation can be used in estimating the blade stresses for all propellers in the root area (r/R < 0.5) for final approval.

$$\sigma_{st} = A_1 \frac{M_{BL}}{100 \times ct^2} \qquad \text{MPa}$$

where: constant A_1 is the $\frac{actual\ stress}{stress\ obtained\ with\ beam\ equation}$. If the actual value is not available, A_1 should be taken as 1.6. $M_{BL} = (0.75 - r/R)RF$, for relative radius r/R<0.5, where F is the maximum of F_b and F_f, whichever is greater.

(2) Acceptability criterion for static loads

The following criterion for calculated blade stresses shall be fulfilled:

$$\frac{\sigma_{ref\,2}}{\sigma_{st}} \geq 1.3$$

where:σ_{st} ——calculated stress for the design loads. If FE analysis is used in estimating the stresses, von Mises stresses shall be used.

(3) Fatigue design of propeller blade

For materials with a two slope S-N curve the fatigue calculations defined in this chapter are not required if the following criterion is fulfilled.

$$\sigma_{\exp} \geqslant B_1 \cdot \sigma_{ref\,2}^{B_2} \cdot \log\left(N_{ice}\right)^{B_3}$$

where: B_1, B_2 and B_3 are coefficients for propellers given in Table 13.3.6.2(3).

Value of B_1, B_2 and B_3 **Table 13.3.6.3(3)**

Coefficient	Open propeller	Ducted propeller
B_1	0.00328	0.00223
B_2	1.0076	1.0071
B_3	2.101	2.471

Where the above criterion is not fulfilled the fatigue requirements defined below shall be applied:

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress σ_{fat} that produces the same fatigue damage as the expected load distribution shall be calculated according to Miner's rule and the acceptability criterion for fatigue should be fulfilled as given in this section. The equivalent stress is normalised for 100 million cycles.

The blade stresses at various selected load levels for fatigue analysis are to be taken proportional to the stresses calculated for maximum loads given in section 13.3.5.

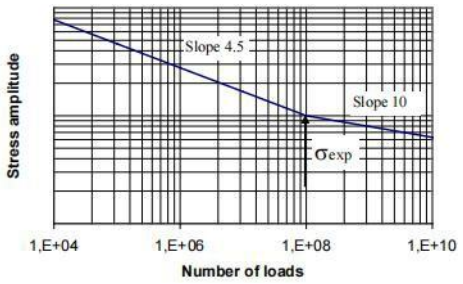
The peak principal stresses σ_f and σ_b are determined from F_f and F_b using FEA. The peak stress range $\Delta\sigma_{max}$ and the maximum stress amplitude σ_{Amax} are determined on the basis of load cases 1 and 3, 2 and 4.

$$\Delta\sigma_{\max} = 2 \cdot \sigma_{A\max} = \left|(\sigma_{ice})_{f\max}\right| + \left|(\sigma_{ice})_{b\max}\right| \qquad \text{MPa}$$

The load spectrum for backward loads is normally expected to have a lower number of cycles than the load spectrum for forward loads. Taking this into account in a fatigue analysis introduces complications that are not justified considering all uncertainties involved.

For the calculation of equivalent stress two types of S-N curves are available. Two slope S-N curve (slopes 4.5 and 10), see Figure 13.3.6.3(3)-1. One slope S-N curve (the slope can be chosen), see Figure 13.3.6.3(3)-2.

The type of the S-N-curve shall be selected to correspond with the material properties of the blade. If the S-N-curve is not known the two slope S-N curve shall be used.



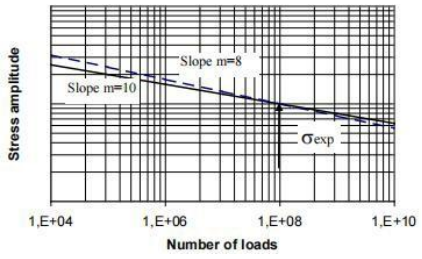


Figure 13.3.6.3(3)-1 Two-slope *S-N* curve **Figure 13.3.6.3(3)-2 Constant-slope *S-N* curve**

① Equivalent fatigue stress

A more general method of determining the equivalent fatigue stress of propeller blades is described in 13.3.6.5, where the principal stresses are considered according to 13.3.5.3 and 13.3.5.4 using the Miner's rule. For a total number of load blocks $n_{bl} > 100$, both methods deliver the same result. Therefore, they are regarded as equivalent.

The equivalent fatigue stress for 10^8 cycles which produces the same fatigue damage as the load distribution is:

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{\max} \quad \text{MPa}$$

where:$(\sigma_{ice})_{\max}$ —— mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied, to be determined as follows:

$$(\sigma_{ice})_{\max} = 0.5 \cdot \left((\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max} \right) \quad \text{MPa}$$

where: $(\sigma_{ice})_{f\max}$ is principal stress resulting from forward load, $(\sigma_{ice})_{b\max}$ is principal stress resulting from backward load.

In the calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 or case 2 and case 4 are considered as pairs for $(\sigma_{ice})_{f\max}$ and $(\sigma_{ice})_{b\max}$. Case 5 is excluded from the fatigue analysis.

② Calculation of parameter ρ for two-slope S-N curve

When $5 \times 10^6 \le N_{ice} \le 1 \times 10^8$, the error of the following method to determine the parameter ρ is sufficiently small.

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula.

$$\rho = C_1 \cdot (\sigma_{ice})_{\max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, is the blade material fatigue strength at 10^8 load cycles, see 13.3.6.3(3)④.

The coefficients C_1, C_2, C_3 and C_4 are given in Table 13.3.6.3(3)②.

Value of C_1, C_2, C_3 and C_4 **Table 13.3.6.3(3)②**

Coefficient	Open propeller	Ducted propeller
C_1	0.000747	0.000534
C_2	0.0645	0.0533
C_3	−0.0565	−0.0459
C_4	2.22	2.584

③ Calculation of parameter ρ for constant-slope S-N curve

For materials with a constant-slope S-N curve, see Figure 13.3.6.3(3)-2, the factor ρ shall be calculated from the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R} \right)^{1/m} \left[\ln(N_{ice}) \right]^{-1/k}$$

where: k —— shape parameter of the Weibull distribution, k=1.0 for ducted propellers and k=0.75 for open propellers;

N_R —— reference number of load cycles (=10^8);

G —— Values for the parameter G are given in Table 13.3.6.3(3) ③ below. Linear interpolation may be used to calculate the value of G for m/k ratios other than those given in the Table 13.3.6.3(3)③.

Value for the parameter *G* for different m/k ratios **Table 13.3.6.3(3)③**

m/k	*G*	*m/k*	*G*	*m/k*	*G*	*m/k*	*G*
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.623E6		

④ Acceptability criterion for fatigue

The equivalent fatigue stress σ_{fat} at all locations on the blade shall fulfil the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geqslant 1.5$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, in MPa;

$\gamma_{\varepsilon 1}$—— reduction factor due to scatter (equal to one standard deviation);

$\gamma_{\varepsilon 2}$ —— reduction factor for test specimen size effect;

σ_{exp} in Table 13.3.6.3(3)④ has been defined from the results of constant amplitude loading fatigue tests at 10^7 load cycles and 50% survival probability and has been extended to 10^8 load cycles. Fatigue strength values and correction factors other than those given in Table 13.3.6.3(3)④ may be used, provided the values are determined under conditions approved by ISC.

Mean fatigue strength σ_{exp} for different material types at 10^8 load cycles and stress ratio r = -1 with a survival probability of 50%

Table 13.3.6.3(3)④

Bronze and brass（a=1.0）		Stainless steel（a=0.05）	
Mn-Bronze, Cu1 (high tensile brass)	84 MPa	Ferritic (12Cr 1Ni)	144 MPa①
Mn-Ni-Bronze, Cu2 (high tensile brass)	84 MPa	Martensitic (13Cr 4Ni/13Cr 6Ni)	156 MPa
Ni-Al-Bronze, Cu3	120 MPa	Martensitic (16Cr 5Ni)	168 MPa
Mn-Al-Bronze, Cu4	113 MPa	Austenitic (19Cr 10Ni)	132 MPa

Note: ① This value may be used, provided a perfect galvanic protection is active. Otherwise a reduction of about 30 MPa shall be applied.

The S-N curve characteristics are based on two slopes, the first slope 4.5 is from 1000 to 10^8 load cycles; the second slope 10 is above 10^8 load cycles.

The maximum allowable stress for one or low number of cycles is limited to σ_{ref2}/S, with S =1.3 for static loads.

The fatigue strength σ_{fat} is the fatigue limit at 100 million load cycles.

The geometrical size factor ($\gamma_{\varepsilon 2}$) is:

$$\gamma_{\varepsilon 2} = 1 - a \cdot \ln\left(\frac{t}{0.025}\right)$$

where:a —— as given in Table 13.3.6.3(3)④;

t —— the maximum blade thickness at the considered point.

The mean stress effect γ_m is:

$$\gamma_m = 1.0 - \left(\frac{1.4 \cdot \sigma_{mean}}{R_m}\right)^{0.75}$$

The following values should be used for the reduction factors if actual values are not available:

$\gamma_{\varepsilon 1}$ = 0.85, γ_v = 0.75, γ_m=0.75.

13.3.6.4 Blade bolts, propeller hub and CP mechanism

(1) General

The blade bolts, CP mechanism, propeller boss and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum static and fatigue design loads (as applicable), as defined in 13.3.5.3, 13.3.5.4, 13.3.5.5 and 13.3.6.3. The safety factor against yielding due to static loads and against fatigue shall be greater than 1.5, if not stated otherwise. The safety factor for loads, resulting from propeller blade failure as defined in 13.3.5.6 shall be greater than 1.0 against yielding.

Provided that calculated stresses duly considering local stress concentrations are less than yield strength, or maximum of 70% of tensile strength of respective materials, detailed fatigue analysis is not required. In all other cases components shall be analysed for cumulative fatigue. An approach similar to that used for shafting assessment may be applied (13.3.6.5).

(2) Blade bolts

Blade bolts shall withstand the following bending moment considered around a tangent on bolt pitch circle, or any other relevant axis for non-circular joints, parallel to considered root section:

$$M_{bolt} = S \cdot F_{ex}(0.8\frac{D}{2} - \mathrm{r}_{bolt}) \qquad \text{kNm}$$

where: r_{bolt} —— radius to the bolt plane;

S —— 1.0 safety factor.

Blade bolt pre-tension shall be sufficient to avoid separation between mating surfaces when the maximum forward and backward ice loads defined in 13.3.5.3 and 13.3.5.4 (open and ducted propellers respectively) are applied. For conventional arrangements, the following formula may be applied:

$$d_{bb} = 41 \cdot \sqrt{\frac{F_{ex}(0.8D - d) \cdot \mathrm{S} \cdot \alpha}{R_{p0.2} \cdot z_{bb} \cdot PCD}} \qquad \text{mm}$$

where: α —— 1.6 torque guided tightening; 1.3 elongation guided; 1.2 angle guided; 1.1 elongated by other additional means; other factors may be used, if evidence is demonstrated;

d_{bb}—— effective diameter of blade bolt in way of thread, in mm;

z_{bb}—— number of blade bolts;

S —— 1.0 safety factor.

(3) CP mechanism

Separate means, e.g. dowel pins, shall be provided in order to withstand the spindle torque resulting from blade failure Q_{sex} (see 13.3.5.6(2)) or ice interaction Q_{smax} (see 13.3.5.5(1)) whichever is greater. Other components of the CP mechanism shall not be damaged by the maximum spindle torques (Q_{smax}, Q_{sex}). One third of the spindle torque is assumed to be consumed by friction, if not otherwise documented trough further analysis.

The diameter of fitted pins between the blade and blade carrier can be calculated using the formula:

$$d_{fp} = 66 \cdot \sqrt{\frac{Q_s - Q_{fr}}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \qquad \text{mm}$$

where: Q_s —— $\max(S \cdot Q_{s\max}, S \cdot Q_{sex})$, in kNm;

S —— 1.3 for $Q_{s\max}$, 1.0 for Q_{sex};

Q_{fr} —— friction between connected surfaces,= $0.33 \cdot Q_s$, in kNm. ISC may approve alternative Q_{fr} calculation according to reaction forces due to F_{ex}, or F_f, F_b whichever is relevant, utilising a friction coefficient = 0.15.

The stress in the actuating pin can be estimated by:

$$\sigma_{vMises} = \sqrt{\left(\frac{F_m \cdot \frac{h_{pin}}{2}}{\frac{\pi \cdot d_{pin}^{\ 3}}{32}}\right)^2 + 3 \cdot \left(\frac{F_m}{\frac{\pi}{4} \cdot d_{pin}^{\ 2}}\right)^2} \qquad \text{MPa}$$

where: F_m —— $\left(Q_s - Q_{fr}\right) / l_m$, in kN;

l_m —— distance pitching centre of blade – axis of pin, in m;

h_{pin}—— height of actuating pin, in mm;

d_{pin}—— diameter of actuating pin, in mm;

Q_{fr}—— friction torque in blade bearings acting on the blade palm and caused by the reaction forces

due to F_{ex} , or F_f , F_b whichever is relevant; taken to one third of spindle torque Q_s, in kNm.

The blade failure spindle torque Q_{sex} shall not lead to any consequential damage.

Fatigue strength is to be considered for parts transmitting the spindle torque from the blade to a servo system considering the ice spindle torque acting on one blade. The maximum amplitude Q_{samax} is defined as:

$$Q_{samax} = \frac{Q_{sb} + Q_{sf}}{2} \quad \text{kNm}$$

where: Q_{sb} —— spindle torque due to $|F_b|$, in kNm;

Q_{sf} —— spindle torque due to $|F_f|$, in kNm.

(4) Servo pressure

The design pressure for the servo system shall be taken as the pressure caused by Q_{smax} or, Q_{sex} when not protected by relief valves on the hydraulic actuator side, reduced by relevant friction losses in bearings caused by the respective ice loads. The design pressure shall in any case not be less than relief valve set pressure.

13.3.6.5 Propulsion line components

The ultimate load resulting from total blade failure F_{ex} as defined in 13.3.5.6 shall consist of combined axial and bending load components, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for all shaft line components.

The shafts and shafting components, such as bearings, couplings and flanges shall be designed to withstand the operational propeller/ice interaction loads as given in 13.3.5.

The given loads are not intended to be used for shaft alignment calculation.

Cumulative fatigue calculations shall be conducted according to the Miner's rule. A fatigue calculation is not necessary, if the maximum stress is below fatigue strength at 10^8 load cycles.

The torque and thrust amplitude distribution (spectrum) in the propulsion line is to be taken as (because Weibull exponent k = 1), with Figure 13.3.6.5-1 as an example:

$$Q_A(\mathrm{N}) = Q_{A\max} \cdot \left[1 - \frac{\log(N)}{\log(Z \cdot N_{ice})}\right]$$

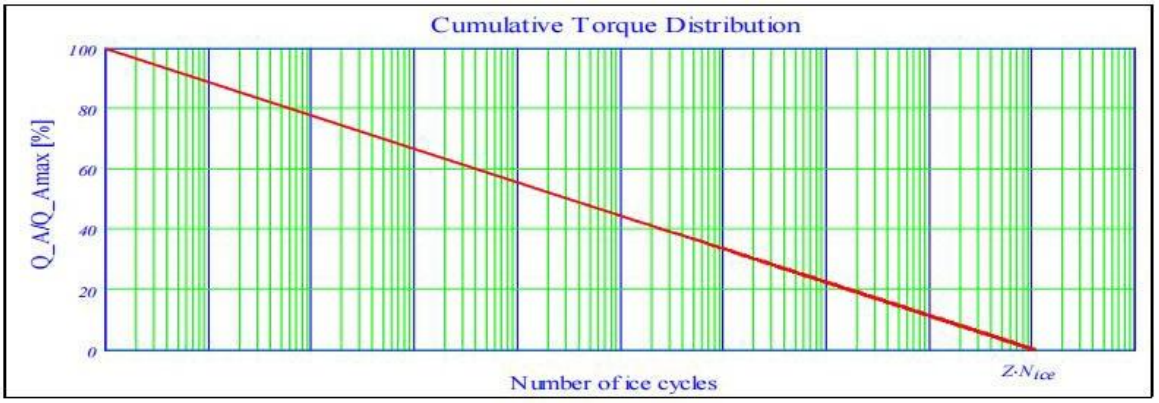


Figure 13.3.6.5-1 Cumulative torque distribution

The number of load cycles in the load spectrum is defined as $Z \cdot N_{ice}$.

The Weibull exponent should be considered as k = 1.0 for both open and ducted propeller torque and bending forces. The load distribution is an accumulated load spectrum, and the load spectrum should be divided into a minimum of ten load blocks when using the Miner summation method.

The load spectrum used counts the number of cycles for 100% load to be the number of cycles above the next step, e.g. 90 % load. This ensures that the calculation is on the conservative side. Consequently, the fewer stress blocks used the more conservative the calculated safety margin, see Figure 13.3.6.5-2.

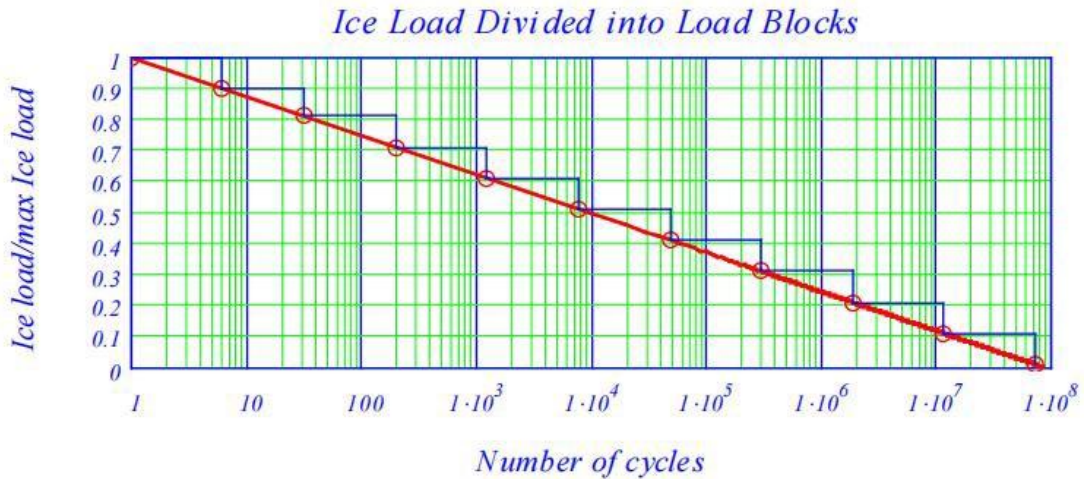


Figure 13.3.6.5-2 Example of ice load distribution (spectrum) for the shafting (k = 1)

The load spectrum is divided into n_{bl}-number of load blocks for the Miner summation method.
The following formula can be used for calculation of the number of cycles for each load block.

$$n_i = N_{ice}^{1-\left(1-\frac{i}{n_{bl}}\right)^k} - \sum_{i=1}^{i} n_{i-1}$$

where:i —— single load block, n_{bl} is the number of load blocks.
(1) Propeller fitting to the shaft
Keyless cone mounting or flange mounting may be generally used for propeller fitting to the shaft. Key mounting alone is not permitted.

① Keyless cone mounting

The friction capacity (at 0℃) shall be at least S = 2.0 times the highest peak torque Q_{peak} as determined in 13.3.5.9 without exceeding the permissible hub stresses.
The necessary surface pressure can be determined as:

$$p_{0°C} = \frac{2 \cdot S \cdot Q_{peak}}{\pi \cdot \mu \cdot D_S^2 \cdot L \cdot 10^3} \qquad \text{MPa}$$

where: μ —— 0.15 for steel-steel; 0.13 for steel-bronze;
D_S —— the shrinkage diameter at the mid-length of the taper, in m;
L —— the effective length of taper, in m.
Above friction coefficients may be increased by 0.04 if glycerine is used in wet mounting.

② Flange mounting

The flange thickness is to be at least 25% of the required aft end shaft diameter.
Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet unless the flange thickness is increased correspondingly.
The flange fillet radius is to be at least 10% of the required shaft diameter.
The diameter of shear pins shall be calculated according to the following equation:

$$d_{pin} = 66 \cdot \sqrt{\frac{Q_{peak} \cdot S}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \qquad \text{mm}$$

where:Z_{pin}—— number of shear pins;
S —— 1.3 safety factor.

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding of the bolts. The following equation should be applied:

$$d_b = 41 \cdot \sqrt{\frac{F_{ex} \cdot (0.8 \cdot D / PCD + 1) \cdot \alpha}{R_{p0.2} \cdot z_b}} \qquad \text{mm}$$

where: α —— 1.6 torque guided tightening, 1.3 elongation guided, 1.2 angle guided, 1.1 elongated by other additional means, other factors may be used, if evidence is demonstrated;

d_b —— diameter flange bolt, in mm;

z_b —— number of flange bolts.

(2) Propeller shaft

The propeller shaft is to be designed to fulfil the following:

① The blade failure load F_{ex} (13.3.5.6) applied parallel to the shaft (forward or backwards) shall not cause yielding. The bending moment need not to be combined with any other loads. The diameter in way of the aft stern tube bearing shall not be less than:

$$d_p = 160 \cdot \sqrt[3]{\frac{F_{ex} \cdot D}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where:d_p —— propeller shaft diameter, in mm;

d_i —— propeller shaft inner diameter, in mm, 0 for solid shaft.

Forward from the aft stern tube bearing the shaft diameter may be reduced based on direct calculation of the actual bending moment, or by the assumption that the bending moment caused by F_{ex} is linearly reduced to 25% at the next bearing and in front of this linearly to zero at third bearing.

Bending due to maximum blade forces F_b and F_f have been disregarded since the resulting stress levels are much lower than the stresses caused by the blade failure load.

② The stresses due to the peak torque Q_{peak} shall have a minimum safety factor of S =1.5 against yielding in plain sections and S =1.0 in way of stress concentrations in order to avoid bent shafts.

Considering peak torque, the minimum shaft diameter is not to be less than that calculated from the following formulae:

Plain shaft:

$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

Notched shaft:

$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S \cdot \alpha_t}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where:α_t —— local stress concentration factor in torsion.

Notched shaft diameter shall in any case not be less than the required plain shaft diameter.

③ The torque amplitudes (13.3.5.8(4)) with the corresponding number of load cycles shall be used in an accumulated fatigue evaluation where the safety factor is S_{fat} =1.5. If the plant has high engine excited torsional vibrations (e.g. direct coupled 2-stroke engines), this shall also be considered.

④ The fatigue strengths σ_F and τ_F (3 million cycles) of shaft materials may be assessed on the basis of the material's yield or 0.2% proof strength as:

$$\sigma_F = 0.436 \cdot R_{p0.2} + 77 = \tau_F \cdot \sqrt{3} \quad \text{MPa}$$

This is valid for small polished specimens (no notch) and reversed stresses, see "VDEH 1983 Bericht Nr. ABF11 Berechnung von Wöhlerlinien für Bauteile aus Stahl".

The high cycle fatigue (HCF) is to be assessed based on the above fatigue strengths, notch factors (i.e. geometrical stress concentration factors and notch sensitivity), size factors, mean stress influence and the required safety factor of 1.6 at 3 million cycles increasing to 1.8 at 10^9 cycles.

The low cycle fatigue (LCF) representing 10^4 cycles is to be based on the smaller value of yield or 0.7 of tensile strength/√3. The criterion utilises a safety factor of 1.25.

The LCF and HCF as given above represent the upper and lower knees in a stress-cycle diagram. Since the required safety factors are included in these values, a Miner sum of unity is acceptable.

(3) Intermediate shaft

The intermediate shafts are to be designed to fulfil the requirements of 13.3.6.5(2)②~④.

(4) Shaft connections

Shaft connections are to satisfy the following requirements. Keyed connections (except for splined shaft) are not to be used.

① Shrink fit couplings (keyless)

See 13.3.6.5(1)①. A safety factor of S = 1.8 shall be applied.

② Flange mounting

The flange thickness is to be at least 20% of the required shaft diameter.

Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet unless the flange thickness is increased correspondingly.

The flange fillet radius is to be at least 8% of the shaft diameter.

The diameter of ream fitted (light press fit) bolts shall be chosen so that the peak torque is transmitted with a safety factor of 1.9. This accounts for a prestress. Pins shall transmit the peak torque with a safety factor of 1.5 against yielding (see the formula in 13.3.6.5(1)②) .

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding.

③ Splined shaft connections

Splined shaft connections can be applied where no axial or bending loads occur. A safety factor of S = 1.5 against allowable contact and shear stress resulting from peak torque shall be applied.

(5) Gear transmissions

① Shafts

Shafts in gear transmissions shall meet the same safety level as intermediate shafts, but where relevant, bending stresses and torsional stresses shall be combined (e.g. by von Mises for static loads). Maximum permissible deflection in order to maintain sufficient tooth contact pattern shall be considered for the relevant parts of the gear shafts.

② Gearing

The gearing shall fulfil following three acceptance criteria: tooth root stresses, pitting of flanks, and scuffing. In addition to above 3 criteria subsurface fatigue may need to be considered.

Common for all criteria is the influence of load distribution over the face width. All relevant parameters are to be considered, such as elastic deflections (of mesh, shafts and gear bodies), accuracy tolerances, helix modifications, and working positions in bearings (especially for multiple input single output gears).

The load spectrum (see 13.3.6.5) may be applied in such a way that the numbers of load cycles for the output wheel are multiplied by a factor of (number of pinions on the wheel / number of propeller blades Z). For pinions and wheels operating at higher speeds the numbers of load cycles are found by multiplication with the gear ratios. The peak torque (Q_{peak}) is also to be considered during calculations.

Cylindrical gears can be assessed on the basis of the international standard ISO 6336 Pt. 1-6, provided that “method B” is used. Equivalent requirements in Appendix 1, Chapter 10, PART THREE of the Rules can also be applied.

For Bevel Gears the methods or standards used or acknowledged by ISC can be applied provided that they are properly calibrated.

Tooth root safety shall be assessed against the peak torque, torque amplitudes (with the pertinent average torque) as well as the ordinary loads (open water free running) by means of accumulated fatigue analyses. The resulting factor of safety is to be at least 1.5. (Ref ISO 6336 Pt 1, 3 and 6 and Appendix 1, Chapter 10, PART THREE of the Rules)

The safety against pitting shall be assessed in the same way as tooth root stresses, but with a minimum resulting safety factor of 1.2. (Ref ISO 6336 Pt 1, 2 and 6 and Appendix 1, Chapter 10, PART THREE of the Rules)

The scuffing safety (flash temperature method – ref. ISO/TR 13989-1 and ISO/TR 13989-2) based on the peak torque shall be at least 1.2 when the FZG class of the oil is assumed one stage below specification.

The safety against subsurface fatigue of flanks for surface hardened gears (oblique fracture from active flank to opposite root) is to be assessed at the discretion of ISC. (It should be noted that high overloads can initiate subsurface fatigue cracks that may lead to a premature failure. In lieu of analyses UT inspection intervals may be used.)

③ Bearings

See 13.3.6.5(9).

④ Gear wheel shaft connections

The torque capacity shall be at least 1.8 times the highest peak torque Q_{peak} (at considered rotational speed) as determined in 6.5 without exceeding the permissible hub stresses of 80% yield.

(6) Clutches

Clutches shall have a static friction torque of at least 1.3 times the peak torque Q_{peak} and dynamic friction

torque 2/3 of the static.

Emergency operation of clutch after failure of e.g. operating pressure shall be made possible within reasonably short time. If this is arranged by bolts, it shall be on the engine side of the clutch in order to ensure access to all bolts by turning the engine.

(7) Elastic couplings

There shall be a separation margin of at least 20% between the maximum response torque and the torque where any mechanical twist limitation and/or the permissible maximum torque of the elastic coupling, valid for at least a single load cycle, is reached, expressed as follows:

$$Q_{peak} < 0.8 \cdot T_{k\max}(N=1) \qquad \text{kNm}$$

$$\frac{Q_r(N=x)}{Q_r(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})} \qquad \text{and}$$

$$\frac{Q_A(N=x)}{Q_A(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.

$$Q_r(\mathrm{N}=5\times10^4) \cdot S < T_{k\max}(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

$$Q_r(\mathrm{N}=1\times10^6) \cdot S < T_{kv} \qquad \text{kNm}$$

$$Q_A(\mathrm{N}=5\times10^4) \cdot S < \Delta T_{k\max}(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.

A sufficient fatigue strength shall be demonstrated at design torque level $Q_r(N=x)$ and $Q_A(N=x)$. This may be demonstrated by interpolation in a Weibull torque distribution (similar to Figure 13.3.6.5-1):

S is the general safety factor for fatigue, equal to 1.5.

See figures below when using the above formulae:

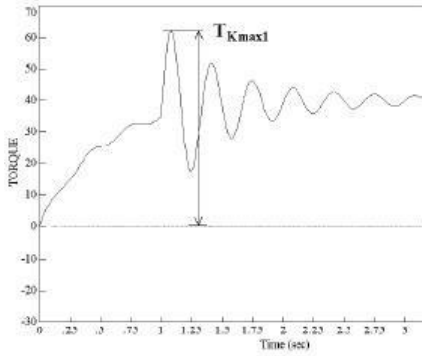


Figure 13.3.6.5(7)-1

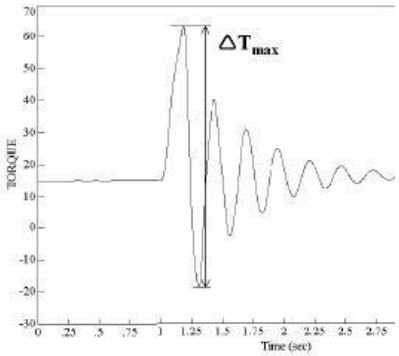


Figure 13.3.6.5(7)-2

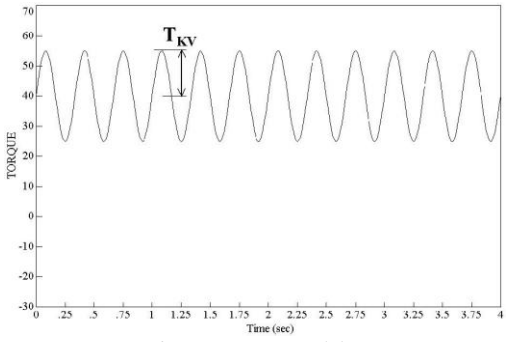


Figure 13.3.6.5(7)-3

The torque amplitude (or range Δ) shall not lead to fatigue cracking, i.e. exceeding the permissible vibratory torque. The permissible torque may be determined by interpolation in a Weibull torque distribution where T_{kmax1} respectively ΔT_{kmax} refer to 50000 cycles and T_{kv} refer to 10^6 cycles. See illustration in below Figures 13.3.6.5(7)-1, 13.3.6.5(7)-2 and 13.3.6.5(7)-3.

$$T_{k\max1}(\mathrm{N}=5\times10^4) \geq Q_r(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

(8) Crankshafts

Special considerations apply for plants with large inertia (e.g. flywheel, tuning wheel or PTO) in the non-driving end front of the engine (opposite to main power take off).

(9) Bearings

The aft stern tube bearing as well as the next shaft line bearing are to withstand F_{ex} as given in 13.3.5.6, in such a way that the ship can maintain operational capability. Rolling bearings are to have an L_{10a} lifetime of at least 40 000 hours according to ISO 281. Thrust bearings and their housings are to be designed to withstand with the maximum response thrust specified in 13.3.5.7 and the axial force resulting from the blade failure load specified in 13.3.5.6. For the purpose of calculation, except for F_{ex}, the shafts are assumed to rotate at rated speed. For pulling propellers special consideration is to be given to loads from ice interaction on the propeller hub.

(10) Seals

Seals are to prevent egress of pollutants and be suitable for the operating temperatures. Contingency plans for preventing the egress of pollutants under failure conditions are to be documented.

Seals installed are to be suitable for the intended application. The manufacturer is to provide service experience in similar applications and/or testing results for consideration by ISC.

13.3.6.6 Azimuthing main propulsors

In addition to the above requirements, special consideration shall be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of load cases shall reflect the way the thrusters are intended to operate on the specific ship. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller shall be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow shall be considered. The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the loss of a blade without damage. The loss of a blade shall be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the thruster body.

Azimuth thrusters shall also be designed for estimated loads caused by thruster body/ice interaction. The thruster body shall withstand the loads obtained when the maximum ice blocks, which are given in section 13.3.5.2, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body should be considered. The thickness of the sheet should be taken as the thickness of the maximum ice block entering the propeller, as defined in section 13.3.5.2.

13.3.7 Prime movers

13.3.7.1 Engines are to be capable of being started and running the propeller in bollard condition. Propulsion plants with CP propeller are to be capable being operated even when the CP system is at full pitch as limited by mechanical stoppers.

13.3.7.2 The arrangement of compressed air for mechanical starting arrangements (including capacity of air receivers and charging capacity) is to satisfy relevant requirements of 9.5.1, Chapter 9, PART THREE of the Rules. In addition, for a ship with the ice class PC1~PC6, if its propulsion engine has to be reversed for going astern, the charging time required by 9.5.1.2, Chapter 9, PART THREE of the Rules is not to exceed 0.5h.

13.3.7.3 Provisions shall be made for heating arrangements to ensure ready starting from cold of the emergency power units at an ambient temperature applicable to the Polar Class of the ship. Emergency power units shall be equipped with starting devices with a stored energy capability of at least three consecutive starts at the above mentioned temperature. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent mean of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

13.3.8 Equipment fastening loading accelerations

13.3.8.1 Essential equipment and supports shall be suitable for the accelerations as indicated in the following paragraphs. Accelerations are to be considered as acting independently.

13.3.8.2 Longitudinal Impact Accelerations, a_l

Maximum longitudinal impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_l = (F_{IB} / \Delta)\ \{[1.1\ tan(\gamma + \varphi)] + [7\frac{H}{L}]\} \qquad \text{m/s}^2$$

where:φ ——maximum friction angle between steel and ice, normally taken as 10 degrees;

γ ——bow stem angle at waterline, in degrees;

Δ ——displacement, in kt;

L ——length between perpendiculars, in m;

H ——distance in meters from the water line to the point being considered, in m;

F_{IB} ——vertical impact force, defined in 13.2.13.2(1).

13.3.8.3 Vertical Accelerations, a_v

Combined vertical impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_v = 2.5\ (F_{IB} / \Delta)F_X \qquad \text{m/s}^2$$

where: F_{IB} and Δ are the same as 13.3.8.2;

F_X——1.3 at FP, 0.2 at midships, 0.4 at AP, 1.3 at AP for vessels conducting ice breaking astern. Intermediate values to be interpolated linearly.

13.3.8.4 Transverse impact acceleration, a_t

Combined transverse impact acceleration at any point along hull girder is calculated by the following formula:

$$a_t = 3F_i \frac{F_X}{\Delta} \qquad \text{m/s}^2$$

where: Δ is the same as 13.3.8.2;

F_i ——total force normal to shell plating in the bow area due to oblique ice impact, defined in 13.2.3.2(2);

F_X—— 1.5 at FP, 0.25 at midships, 0.5 at FP, 1.5 at AP for vessels conducting ice breaking astern. Intermediate values to be interpolated linearly.

13.3.9 Auxiliary systems

13.3.9.1 Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means should be provided to purge the system of accumulated ice or snow.

13.3.9.2 Means should be provided to prevent damage to tanks containing liquids due to freezing.

13.3.9.3 Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

13.3.10 Sea Inlets and Cooling Water Systems

13.3.10.1 Cooling water systems for machinery that is essential for the propulsion and safety of the vessel, including sea chest inlets, shall be designed for the environmental conditions applicable to the ice class.

13.3.10.2 At least two sea chests are to be arranged as ice boxes (sea chests for water intake in severe ice conditions) for ice class PC1 to PC5 inclusive. The calculated volume for each of the ice boxes shall be at least $1m^3$ for every 750 kW of the totally installed power. For PC6 and PC7 there shall be at least one ice box located preferably near centre line.

13.3.10.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

13.3.10.4 Sea inlet valves are to be secured directly to the ice boxes. The valve shall be a full bore type.

13.3.10.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected directly to the shell.

13.3.10.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

13.3.10.7 Efficient means are to be provided to re-circulate cooling seawater to the ice box. Total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

13.3.10.8 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

13.3.10.9 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. The means of clearing is to be of a type using low pressure steam. Clearing pipes are to be provided with screw-down type non return valves.

13.3.11 Ballast tanks

13.3.11.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing

tanks located above the water line and where otherwise found necessary.

13.3.12 Ventilation systems

13.3.12.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship at locations where manual de-icing is possible. Anti-icing protection of the air inlets may be accepted as an equivalent solution (De-icing and anti-icing are defined in Chapter 23 of this PART) to location on both sides of the ship and manual de-icing. Notwithstanding the above, multiple air intakes are to be provided for the emergency generating set and are to be as far apart as possible.

13.3.12.2 The temperature of the inlet air shall be suitable for the safe operation of the machinery and the thermal comfort in the accommodation. Accommodation and ventilation air intakes shall be provided with means of heating, if needed.

13.3.13 Steering systems

13.3.13.1 The design ice force on rudder shall be transmitted to the rudder stops required by 13.1.5.8, Chapter 13, PART THREE of the Rules without damage to the steering system.

An ice knife shall in general be fitted to protect the rudder in centre position. The ice knife shall extend below BWL. Design forces shall be determined according to the 13.2.15 of this Chapter.

13.3.13.2 The rudder actuator is to be designed for a holding torque obtained by multiplying the open water torque (considering however a maximum speed of 18 knots), by following factors in Table 13.3.13.2:

Ice class factors of steering system **Table 13.3.13.2**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Factor	5	5	3	3	3	1.5	1.5

13.3.13.3 The design pressure for calculations to determine the scantlings of the rudder actuator is to be at least 1.25 times the maximum working pressure corresponding to the holding torque defined above.

13.3.13.4 The rudder actuator is to be protected by torque relief arrangements, assuming the following turning speeds listed in Table 13.3.13.4 [deg/s] without an undue pressure rise (see 13.1.7.2(2), Chapter 13, PART THREE of the Rules for undue pressure rise). If the rudder and actuator design can withstand such rapid loads, this special relief arrangement is not necessary and a conventional one may be used instead (13.1.7.2, Chapter 13, PART THREE of the Rules).

Steering gear turning speeds **Table 13.3.13.4**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	10	10	7.5	7.5	7.5	6	6

13.3.13.5 Additionally for icebreakers, fast-acting torque relief arrangements are to be fitted in order to provide effective protection of the rudder actuator in case of the rudder being pushed rapidly hard over against the stops.

For hydraulically operated steering gear, the fast-acting torque relief arrangement is to be so designed that the pressure cannot exceed 115% of the set pressure of the safety valves when the rudder is being forced to move at the speed indicated in Table 13.3.13.5, also when taking into account the oil viscosity at the lowest expected ambient temperature in the steering gear compartment.

For alternative steering systems the fast-acting torque relief arrangement is to demonstrate an equivalent degree of protection to that required for hydraulically operated arrangements.

Steering gear turning speeds for icebreaker s **Table 13.3.13.5**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	40	40	20	20	20	15	15

13.3.14 Alternative design

13.3.14.1 As an alternative to this Section – a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

CHAPTER 14 REDUNDANT PROPULSION SYSTEMS

Section 1 GENERAL PROVISIONS

14.1.1 General requirements

14.1.1.1 This Chapter applies to ships having one of the class notations specified in 14.1.3 below. Redundant propulsion systems are to comply with the provisions of this Chapter in addition to other relevant requirements of the Rules.

14.1.1.2 The system design is to ensure that at least the following functions are maintained in the event of a single failure as defined in 14.1.4.1:

(1) The propulsion system will enable the ship to maintain a full load speed not less than 7 knots while heading into BF 3 weather conditions with corresponding wave conditions. Adequate steering capability is also to be maintained at this speed.

(2) The propulsion system will enable the ship to maintain its position and heading while heading into BF 8 weather conditions with corresponding wave conditions. The results of model testing may be accepted.

(3) Availability of safety systems, including fire-fighting systems, bilge system, navigation lights, communication apparatus, life-saving appliances.

(4) Habitability conditions, including minimum lighting, ventilation, galleys, refrigerated stores, drinking water or evaporator services.

14.1.2 Definitions

14.1.2.1 For the purpose of this Section, the following definitions are applicable:

(1) Propulsion system is a system designed to provide thrust to a ship, consisting of one or more propulsion machines, one or more propulsors, one or more steering system, all necessary auxiliaries and associated control, alarm and safety systems.

(2) Propulsion machine is a device (e.g. diesel engine, turbine, electrical motor, etc.) which develops mechanical energy to drive a propulsor.

(3) Steering system is a system designed to control the direction of movement of a ship, including the rudder, steering gear, etc.

(4) Propulsor is a device (e.g. propeller, waterjet) which imparts force to a column of water in order to propel a ship, together with any equipment necessary to transmit the power from the propulsion machinery to the device (e.g. shafting, gearing, etc.).

(5) Auxiliary services system means all support systems (e.g. fuel oil system, lubricating oil system, cooling water system, compressed air and hydraulic systems, etc.) which are required to run propulsion machinery, propulsors, steering systems and generating sets.

14.1.3 Class notations

14.1.3.1 Where requested by the Owner, propulsion systems which are found to comply with the requirements specified in this Chapter may be assigned the following class notations, as appropriate.

(1) PR-1: A ship fitted with two or more propulsion machines but only a single propulsor and steering system.

(2) PR-2: A ship fitted with two or more propulsion machines and also two or more propulsors and steering systems.

(3) PR-1S: A ship fitted with only a single propulsor and steering system but having two or more propulsion machines arranged in separate compartments.

(4) PR-2S: A ship fitted with two or more propulsion machines and also two or more propulsors and steering systems, and having the propulsion machines and associated steering systems arranged in separate compartments.

14.1.4 Single failure

14.1.4.1 For the purpose of this Chapter, a single failure mainly includes but is not limited to the following:

(1) loss of a propulsion machine;

(2) any failure of a non-static component of systems which are necessary for the operation of the propulsion machine or steering gear, including prime movers, controls and monitoring of fuel oil system, lubricating oil system, cooling system, compressed air system;

(3) any failure of heat exchangers, including heat generators, necessary for propulsion (i.e. auxiliary boilers, fuel oil heaters, lubricating oil coolers, fresh water coolers, reduction gear oil coolers);
(4) any failure of any non-static component of fuel oil and lubricating oil transfer system;
(5) any failure of any of the power generating sets;
(6) any failure of any electric apparatus, including the main switchboard, electric motors, transformers, distribution switchboards, panels;
(7) any failure of the propulsor, including propeller, propeller shaft, intermediate shafts, bearings, couplings, reduction gears;
(8) any failure of any static component of the systems which are necessary for the operation of the propulsion machine or steering gear, including integrity of pipes, valves, pipe fittings, pipe supports, tanks;
(9) loss of one compartment due to fire or flooding;
(10) any failure of any component directly caused by a single failure of another component. For example, the complete loss of a main propulsion engine or of any part of the main switchboard is not to impair the proper functioning of the other machinery and equipment. Any of consequence failures are also to be considered.

14.1.4.2 A single failure concept is applied to the class notations as follows:
(1) For PR-1, the single failure concept is applied to the propulsion machines, its auxiliary service systems and its control systems. This notation does not consider failure of the propulsor or steering system, or total loss of the propulsion machinery compartment or steering gear room due to fire or flood.
(2) For PR-2, the single failure concept is applied to the propulsion system. This notation does not consider total loss of the propulsion machinery compartment or steering gear room due to fire or flood.
(3) For PR-1S, the single failure concept is applied as for PR-1**,** but total loss of one of the propulsion machinery compartments due to fire or flood is also considered.
(4) For PR-2S, the single failure concept is applied as for PR-2, but total loss of one of the propulsion machinery compartments or steering gear rooms due to fire or flood is also considered.
(5) For PR-1 and PR-2, any single failure described in 14.1.4.1(8) may not be considered.

14.1.5 Plans and documents

14.1.5.1 The following plans and documents are to be submitted for approval:
(1) Technical specifications for the redundant propulsion system, including all design details to achieve functional objectives;
(2) All plans of arrangement, piping and electrical system and calculations related to the redundant propulsion system;
(3) An Failure Mode and Effect Analysis (FMEA) report;
(4) A testing plan.

14.1.5.2 An operating manual for the redundant propulsion system is to be submitted for reference. The operating manual is to include the following, as a minimum:
(1) ship's name and ISC class number;
(2) simplified diagram and descriptions of the propulsion systems in normal condition;
(3) simplified diagram and descriptions of the propulsion redundancy features;
(4) step-by-step instructions for the use of the redundancy features;
(5) description of the communication systems;
(6) detailed instructions for local propulsion machinery control;
(7) model test and full-scale test report;
(8) propulsion capability in terms of estimated worst sea states.

14.1.5.3 The above required plans and documents, except for the FMEA report, need not be resubmitted if they have been fully covered in plans and documents submitted in compliance with other relevant requirements of the Rules.

14.1.6 Failure Mode and Effect Analysis (FMEA)

14.1.6.1 An FMEA is to be carried out in accordance with the requirements of 14.1.6.2 to 14.1.6.4 for the propulsion systems and their auxiliary service systems to demonstrate that a single failure, as specified in 14.1.4, will not cause loss of all propulsion capability, and that the redundancy design is able to achieve the functions specified in 14.1.1.2. Typical sub-systems to be analyzed include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

14.1.6.2 Methods and procedures for the FMEA may also be referred to the relevant requirements in Appendix 4 of the International Code for the Safety of High-Speed Craft, 2000 adopted by IMO and ISC Guidelines for Application of Failure Mode and Effects Analysis.

14.1.6.3 The FMEA is to be organized in terms of system, equipment and function, and to cover main components of all relevant systems as far as possible. The failure modes and the measures in response to them are to be determined.
14.1.6.4 An FMEA report is to generally cover but not restricted to the following:
(1) description of main components of all relevant systems and functional block diagram showing interactions between them;
(2) all potential failure modes and their causes;
(3) the effects on the system of each failure mode and the severity of consequences;
(4) measures to detect failures;
(5) measures or corrective actions in response to failures; and
(6) testing procedures to verify conclusions of the FMEA, etc.

Section 2 SYSTEM ARRANGEMENT AND DESIGN

14.2.1 Propulsion machinery and propulsors

14.2.1.1 For PR-1 notation, at least two propulsion machines are to be provided. The propulsion machines and auxiliary service systems may be located in the same propulsion machinery compartment.
14.2.1.2 For PR-2 notation, at least two propulsion machines and two propulsors are to be provided. The propulsion machines, shafting, gearing and auxiliary service systems may be located in the same propulsion machinery compartment.
14.2.1.3 For PR-1S notation, at least two propulsion machines are to be provided. The propulsion machines and auxiliary service systems are to be arranged in separate compartments segregated by bulkheads of A-60 class. The gearing and shafting systems are to be separated from the propulsion machines in such a way that a fire or flood in the propulsion machinery compartment does not impair any function specified in 14.1.1.2. The bulkhead segregating gearing and propulsion machinery compartments is to be watertight with at least A-0 class.
14.2.1.4 For PR-2S notation, at least two propulsion machines and two propulsors are to be provided. The propulsion machines, shafting, gearing and auxiliary service systems are to be arranged in separate compartments segregated by watertight bulkheads of A-60 class.
14.2.1.5 For PR-1 and PR-1S notations where only two propulsion machines and one propulsor are provided, efficient means, e.g. clutches, are to be provided to disconnect propulsion machines from the propulsor.

14.2.2 Steering systems

14.2.2.1 For PR-1 and PR-1S notations, the steering system, including rudder and steering gear, only need comply with other relevant requirements of the Rules.
14.2.2.2 For PR-2 notation, at least two steering systems are to be provided. The steering gear and auxiliary service systems may be arranged in the same compartment.
14.2.2.3 For PR-2S notation, at least two steering systems are to be provided. The steering gear and auxiliary service systems are to be arranged in separate compartments segregated by bulkheads of at least A-0 class.

14.2.3 Auxiliary service systems

14.2.3.1 At least two independent auxiliary service systems, including fuel oil service tanks, are to be provided. These two systems may be designed to be completely independent, or with interconnections between them provided that effective means to disconnect or isolate the systems from each other are fitted.
14.2.3.2 For PR-1S and PR-2S notations, a fire or flood in any of the compartments is not to affect auxiliary service systems in continuously supporting the redundant propulsion.
14.2.3.3 Interconnections of auxiliary service systems arranged in separate compartments are not to compromise the fire and watertight integrity of the separating bulkhead, and effective disconnection or isolation means are to be fitted at both sides of the bulkhead. Position status of the disconnection or isolation means is to be provided at the navigation bridge and the centralized control station.

14.2.4 Electrical power systems

14.2.4.1 The power system serving the propulsion system is to be so arranged that it will not accept total black-out as the consequence of any single failure. Single failure is defined as any system or component breakdown of technical nature. For ships with PR-1S and PR-2S notations, single failure is to also include a fire or flood in any of the compartments.

14.2.4.2 Where the ship's essential equipment is fed from one main switchboard, the sections of main bus bars are to be connected with circuit breakers capable of breaking the maximum short circuit current in the system. Such breakers are to be appropriately protected. For ships with PR-1S and PR-2S notations, the sections of main bus bars are to be located in separate compartments segregated by bulkheads of A-60 class. Both ends of the lines linking the sections of main bus bars are to be fitted with appropriately protected circuit breakers.

14.2.4.3 For PR-1S and PR-2S notations, the generating sets and their auxiliary systems, the distribution systems and the power management systems are to be located in separate compartments segregated by bulkheads of A-60 class. Interconnections of systems located in separate compartments are not to compromise the fire and watertight integrity of the segregating bulkhead, and effective disconnection or isolation means are to be fitted at both sides of the bulkhead. Position status of the disconnection or isolation means is to be provided at the navigation bridge and the centralized control station.

14.2.5 Control and monitoring systems

14.2.5.1 Two independent propulsion systems are to be provided with their respective independent control and monitoring systems. If arranged with common parts, these are to be arranged with redundancy so that any single failure can be effectively isolated.

14.2.5.2 For PR-1S and PR-2S notations, the control and monitoring system for the propulsor (e.g. controllable pitch propeller control), including all associated cabling, is to be duplicated in each compartment, and fire or flooding of one compartment is not to adversely affect operation of the propulsor from the other compartment.

14.2.5.3 For PR-2S notation, the control and monitoring system for the steering system, including all associated cabling, is to be duplicated in each compartment, and fire or flooding of one compartment is not to adversely affect control and monitoring of the redundant steering system.

14.2.5.4 Uninterrupted power supply (UPS) is to be provided as backup for the control and monitoring system. For PR-1S and PR-2S notations, at least two UPSs are to be provided.

14.2.6 Interior communication systems

14.2.6.1 For PR-1S and PR-2S notations, the communication cables to each control station are to be routed through an appropriate compartment, and fire or flooding of one compartment is not to adversely affect the interior communication from the control station in another compartment.

14.2.7 Other facilities

14.2.7.1 For PR-1S and PR-2S notations, piping and cabling serving the equipment or systems, which are redundant to each other, is not to be routed through the same compartment. Where this is unavoidable, such pipes could run together in ducts of A-60 class, and such cables in cable ducts of A-60 class. Cable connection boxes are not allowed in such ducts.

14.2.7.2 For PR-1S and PR-2S notations, in case of fire or flooding in one of the compartments arranged with the propulsion system equipment, the availability of fire-fighting systems, bilge system, lighting and ventilation serving another compartment is to be maintained.

14.2.7.3 For PR-1S and PR-2S notations, in case of fire or flooding in one of the compartments arranged with the propulsion system equipment, the availability of facilities related to ship safety and habitability conditions (e.g. fire-fighting, drainage, ventilation, lighting, galleys, refrigerated stores, drinking water, navigation lights, communication apparatus and life-saving appliances) is to be maintained.

CHAPTER 15 ADDITIONAL REQUIREMENTS FOR ELECTRICALLY PROPELLED SHIPS

Section 1 GENERAL PROVISIONS

15.1.1 General requirements

15.1.1.1 The requirements of this Chapter apply to ships using electric motors as main propulsion.

15.1.1.2 In addition to this Chapter, electrically propelled ships are to comply with the applicable provisions of other PARTs and Chapters of the Rules.

15.1.1.3 Ships complying with the provisions of this Chapter are assigned with the following notation: Electrical Propulsion System

15.1.2 Definitions

15.1.2.1 The definitions in this Chapter are as follows:

(1) propulsion motor means electrical motor intended to provide propulsion power.

(2) propulsion generator means generator mainly used for power supply of the propulsion system.

Section 2 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION INSTALLATIONS

15.2.1 General requirements

15.2.1.1 The torque available in the propulsion motors for manoeuvring is to be capable of stopping or reversing the ship in a reasonable time at the maximum service speed.

15.2.1.2 Adequate torque margin is to be provided in propulsion systems to guard against the motor from being pulled out of synchronism during rough weather or during turning in the case of multiple-screw ships, and to ensure a reliable start under all ambient conditions.

15.2.1.3 The lubrication of bearings of propulsion motors, gearing and shafting is to be effective at all normal speeds from creep speed upwards, either ahead or astern. The above shafts and bearings are not to be damaged by slow rotation caused by motor(s) or propeller(s) under all predictable oil temperature conditions.

15.2.1.4 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a common power plant which serves both propulsion and ship service loads.

15.2.1.5 Under no circumstances should a single failure of the electrical or control system cause a permanent failure of the propulsion system.

15.2.1.6 If electric propulsion is the sole means of propulsion for the ship, at least two independent propulsion motors and converters are generally to be provided. When any stator or propulsion motor fails, the remaining propulsion power is to be sufficient to maintain the efficient propulsion of the ship.

15.2.1.7 If the ship is provided with a single shaft-line propulsion system with one electric motor, a separate propulsion system is to be installed, providing power sufficient to maintain efficient propulsion of the vessel.

15.2.1.8 Propulsion systems having two or more generators, or two or more semiconductor converters, or two or more motors on one propeller shaft is to be so arranged that any unit may be taken out of service and disconnected electrically without affecting the operation of the remaining units.

15.2.1.9 The common power plant is to meet the following requirements:

(1) The control system of the plant is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in the propulsion power if necessary.

(2) Where one generating set is out of action, the remaining sets are to be capable of providing all essential and normal ship service loads while maintaining an effective level of propulsion power, i.e. ensuring a speed of not less than 7 knots or half of the design speed, whichever is the greater. Special consideration may be given in exceptional circumstances subject to agreement of ISC.

15.2.2 Harmonics

15.2.2.1 The electric installations are to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor converters.

15.2.2.2 For an electrical network fitted with semiconductor converters, single order harmonics distortion and up to 15th harmonic are not to exceed 5% of the rated voltage, and the distortion is to be reduced with the higher order and gradually reduced to 1% at 100th harmonic. The total harmonic distortion at dedicated systems (e.g. switchboard for electrical propulsion) is not to exceed 10%, otherwise documentation from the manufacturer is to be submitted indicating that the equipment is designed for operation at a higher level of distortion. This may be specially considered by ISC upon agreement among all parties to the contract.
15.2.2.3 The effects of the harmonics of currents and voltages are to be taken into consideration for the design of the propulsion motors.
15.2.2.4 Means (e.g. suitable filters) are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor converters.
15.2.2.5 The total harmonic distortion (THD) of the voltage waveform is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$V_{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100\%$$

where: V_{THD} — the total harmonic distortion;

V_h — rms amplitude of a harmonic voltage of order h;
V_1 — rms amplitude of the fundamental voltage.

15.2.3 Power management system for common power plant

15.2.3.1 For ships fitted with a common power plant, a power management system having the following functions is to be provided:
(1) automatic start-up and parallel operation of standby generators;
(2) preventing overloading the generators, by reducing the propulsion load and/or tripping non-essential loads;
(3) heavy load inquiry;
(4) ensuring even load sharing between on-line generators.

15.2.4 Prime movers

15.2.4.1 Prime movers and their governors are to comply with the requirements of Chapter 7, 8 or 9 of PART THREE of the Rules. The rated power in conjunction with the overloading and load built-up capabilities are to be adequate to supply the power needed during transitional changes under operating conditions of the electrical equipment due to manoeuvring and the heavy sea and weather conditions.
15.2.4.2 Machinery piping systems for the prime movers are to comply with all the requirements specified in Chapter 4 of PART THREE of the Rules applicable to main engines.
15.2.4.3 In the case of parallel operation of propulsion generators, the governing systems used are to permit stable operation to be maintained over the entire operational speed range of the prime movers.
15.2.4.4 During manoeuvring of the ship, the regenerated power produced by the propulsion motor is not to cause tripping due to overspeed, neither to cause dangerous overload of the system. Where necessary, braking resistors are to be provided to absorb excess amounts of regenerated energy and to reduce the speed of rotation of the propulsion motor.
15.2.4.5 The overspeed protective device is to be set to a speed in excess of the highest possible speed during the periods of power regeneration, and the generating set including prime mover is to be so designed that no damage will be raised from an overspeed equal to that at which the governor is set.

15.2.5 Propulsion generators and propulsion motors

15.2.5.1 Variable speed propulsion motors fitted with an integral fan are to be capable of operating at speeds below the rated speed with full-load torque, full-load current, full-load excitation or in similar conditions, and temperature rises are not to exceed the limits given in 3.2.3 of PART FOUR of the Rules.
15.2.5.2 The temperature of the cooling air of propulsion generators and propulsion motors provided with forced air ventilation is to be continuously monitored by means of direct reading thermometers which are readable from outside the machine and a remote audible alarm actuated by suitable temperature detectors.
15.2.5.3 For propulsion generators and propulsion motors fitted with heat exchangers in closed cooling circuits, the flow of primary and secondary coolants is to be monitored. Alternatively, monitoring of winding temperatures plus alarms may be accepted in lieu of the flow monitoring. In addition, consideration is to be given, where necessary, to the provision of devices for detecting leakage of cooling liquid in the machine enclosure and the operation of an associated alarm.

15.2.5.4 The collector rings and commutators are to be suitably arranged for easy maintenance. For purposes of inspection, repair, withdrawal and replacement of the field coils, provision is to be made for easy access to all windings and bearings.
15.2.5.5 Effective means are to be provided for the propulsion motors to prevent condensation and accumulation of moisture when they are out of service. If steam is used for heating purpose, no joints of steam pipes are permitted within the motors.
15.2.5.6 Propulsion motors are to be capable of withstanding the effects of a sudden short circuit at their terminals under all conditions without suffering damage.
15.2.5.7 Stator windings of AC machines and interpole windings of DC machines, rated above 500 kW, are to be provided with embedded temperature sensors. These sensors are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.
15.2.5.8 Stator windings of AC propulsion motors supplied by varied-frequency semiconductor converters are to be capable of withstanding the voltage variation due to action of the high-frequency switch of inverters.
15.2.5.9 Stator windings of AC propulsion motors supplied by semiconductor converters are to be provided with means to restrict generation of shaft current so as to prevent early damage of bearings.
15.2.5.10 Propulsion generators and propulsion motors are to have a protection degree of at least IP 23. High voltage propulsion generators and propulsion motors are to have a protection degree of at least IP 44.
15.2.5.11 Propulsion generators and propulsion motors with semiconductor converters are to be designed for the expected harmonics of the system. A sufficient reserve is to be considered for the temperature rise due to total harmonic distortion.

15.2.6 Excitation

15.2.6.1 The output current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions including short circuit as well as stalling condition. For this reason, attention is to be paid to the strength of shafts and couplings of rotating sets and to the power of their driving machines.
15.2.6.2 Any single fault in the propulsion generators and propulsion motors excitation system is not to result in a total loss of propulsion power.
15.2.6.3 Field circuits are to be provided with means for suppressing voltage rise when a field switch is opened.
15.2.6.4 For Ward-Leonard systems, arrangements for generator and motor excitation are to be such that if the motor excitation circuit is opened by a switch or contactor, the generator excitation circuit is simultaneously interrupted, or the generator voltage is immediately reduced to zero.
15.2.6.5 In constant voltage systems with two or more independently controlled motors in parallel on the same generator(s), the armature circuit-breaker is to be tripped when an excitation circuit is opened by a switch or contactor.
15.2.6.6 If the protection device of the excitation system trips, the respective circuit breaker of the propulsion generator or motor is also to trip and is to be alarmed.
15.2.6.7 Where fuses are used for excitation circuit protection, it is essential that they do not interrupt the field discharge resistor circuit upon rupturing.

15.2.7 Propulsion control

15.2.7.1 Main and local controls are to be provided, independent of any remote or automatic system, to permit effective control of the propulsion equipment. Should the remote control system fail, local operation is to be possible within a reasonably short time and is to have the highest priority.
15.2.7.2 Either manual operation or operation with the aid of power or a combination of both may be used. All manoeuvring switches, field-regulators and controllers are to be operable effortlessly. If failure of the power supply occurs in systems with power-aided control (e.g. with electrical, pneumatic or hydraulic aid), the control of any such device is to be capable of being restored by other suitable means in a short time.
15.2.7.3 When two or more control stations are provided, a selector switch or other means is to be provided for transferring the manoeuvring controls to the designated station. Simultaneous control from more than one control station is not to be possible. Provision is to be made to prevent malfunction due to the transferring of the control stations. In addition, indication is to be located at each control station to indicate which station is in control.
15.2.7.4 Levers for operating contactors, line switches, field switches and similar devices of ahead and astern circuits are to be interlocked to prevent their improper operation causing ahead and astern circuits being energized simultaneously.

15.2.7.5 The reference value transmitters in the control stations and the control equipment are to be so designed that any defect in the desired value transmitters or in the cables between the control station and the propulsion system will not cause a substantial increase in the propeller speed.
15.2.7.6 Measures are to be taken that the control of the propulsion system can be activated only when the designated control lever is in zero position and the system is ready for operation.
15.2.7.7 Each control station is to have an emergency stop device which is independent of the control lever. The emergency stops are to be independent of the normal stop, and separate for each propulsion line. The emergency stop device is to be monitored against wire break and short circuit. The emergency stop device is to be protected against inadvertent action.
15.2.7.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.
15.2.7.9 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action. The control system is to ensure that there is no dangerous overspeed of propulsion motors upon loss of load.
15.2.7.10 Failure of an automatic control system is not to result in the following consequences:
(1) substantial change in the propeller speed and propulsion direction;
(2) total breakdown of power supply system (i.e. blackout);
(3) changes in available power, that is, no start or stop of generators is to occur.

15.2.8 Cables

15.2.8.1 The conductors of cables external to the components of the propulsion plant, other than cables and interconnecting wiring for computers, data loggers or other automation equipment requiring currents of very small value, are to consist of not less than seven strands and have a cross-sectional area of not less than 1.5 mm^2.
15.2.8.2 Propulsion cables are not to have splices or joints, except terminal joints, and all cable terminals of the propulsion system are to be sealed.
15.2.8.3 For determination of current rating of main cables (cables connecting generators to semiconductor converters and cables connecting semiconductor converters to propulsion motors) of the propulsion system, the additional heating effects due to harmonics in the system are to be taken into account.

15.2.9 Protection

15.2.9.1 Over-current protective devices, if fitted in the main circuits, are to be set sufficiently high so that there is no possibility of their action due to the over-current caused by manoeuvring or normal operation in heavy seas, or in floating pack ice.
15.2.9.2 For DC systems in which overspeed of the propulsion motors may occur (due to light loads or loss of propeller, etc.), suitable overspeed protection is to be provided.
15.2.9.3 Where separately driven DC generators are connected electrically in series, means is to be provided to prevent rotation reversal of a generator upon failure of the driving power of its prime-mover.
15.2.9.4 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor converters.
15.2.9.5 Means are to be provided for discriminative tripping or rapid reduction of the magnetic fluxes of generators or motors to ensure that over-currents do not reach the value which may endanger the propulsion plant.
15.2.9.6 Means for earth leakage detection is to be provided for the main propulsion circuit and be arranged to operate an alarm upon the occurrence of an earth fault. Where fault current flowing is liable to cause damage, arrangements for opening the main propulsion circuit are also to be provided. If the neutral is earthed, it is to be through an arrangement which will limit the current not to exceed approximately 20 A upon a fault to earth in the propulsion system.
15.2.9.7 Means are to be provided for earth leakage detection in excitation circuits of propulsion machines, but may be omitted in circuits of brushless excitation systems and of motors rated up to 500 kW.
15.2.9.8 Upon detection of a failure in the generators' excitation systems, an alarm is to be given on the navigation bridge and in the engine control room and actions to bring the system into a safe operational mode are to be automatically executed.
15.2.9.9 In the design of DC machines and their protective systems, consideration is to be given to measures necessary to minimize any damage in the event of short circuit.
15.2.9.10 Direct-current propulsion circuits are not to have fuses. Each circuit is to be protected by overload relays to open the field circuits or by remote-controlled main-circuit interrupting devices.

15.2.9.11 If there is a possibility of blocking the propeller (e.g. during ice-breaking operation), a protection against damage to the propulsion plant is to be provided.
15.2.9.12 Fuses may be provided for filter circuits. Visual and audible alarms are to be provided at the control station for tripping of the fuse.
15.2.9.13 Differential protection or similar protection against internal short-circuit is to be provided for propulsion motors with an output of 1,500 kW or above.
15.2.9.14 The following protection of semiconductor converters is to be provided:
(1) protection against overvoltage in the supply systems to which converters are connected;
(2) protection against over-currents in semiconductor elements during normal operation;
(3) short-circuit protection.
15.2.9.15 Each propulsion transformer is to be protected against primary and secondary side short-circuit. If the primary side of transformers is protected for short-circuit only, overcurrent protection is to be arranged on the secondary side.

15.2.10 Monitoring instrumentation and alarms

15.2.10.1 Alarms and displays associated with the electrical propulsion system are given in Table 15.2.10.1. These alarms and displays are to be located in the centralized control station of the engine room (in the local station if without the centralized control station). Alarms and displays equivalent to those given in the Table may be accepted subject to agreement of ISC. Alarms for safety actions and group alarms for propulsion generators, motors and semiconductor converters are to be provided in the bridge.

Electric propulsion system monitoring, alarm and safety action item list Table 15.2.10.1

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Propulsion generator (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	Prime mover automatic shutdown
	Voltage – off-limits (high/low)		√		√	√		To read all phases
	Frequency – off-limits (high/low)		√		√	√		For AC propulsion generators only
	Current		√			√		To read all phases
	Power		√			√		To indicate power consumed and power available for propulsion in bridge and centralized control station
	Stator windings temperature – high	√	√		√	√		To read all phases; for generators > 500 kW
	Main generator circuit breakers – open/close					√		
	Generator running		√			√		
	Failure of on-line generator				√			
	Transfer of standby generator				√			
	Generator cooling medium temperature – high	√			√	√		If applicable
	Failure of generator cooling pump or fan motor				√			If applicable
	Field voltage and current		√			√		Applicable to electrical excitation system where provided
	Interpole windings temperature – high	√	√		√	√		For DC generators

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Propulsion Motor (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	
	Voltage – off-limits (high/low)		√		√	√		To read all phases.
	Field voltage					√		
	Frequency – off-limits (high/low)				√	√		For AC propulsion motors only. For propulsion motor controlled by frequency converter, the monitoring of the output of frequency converter may be taken as an alternative
	Armature current		√			√		To read all phases
	Field current		√			√		For synchronous motors
	Stator windings temperature – high	√			√	√		To read all phases; for AC motors > 500 kW only
	Motor circuit breakers – open/close					√		
	Motor running		√			√		
	Motor overspeed	√	√	√	√	√	√	For DC propulsion motors
	Failure of on-line motor				√			
	Transfer of standby motor				√			
	Motor cooling medium temperature – high	√			√	√		If applicable
	Failure of cooling pump or fan motor				√			If applicable
	Interpole current		√			√		For DC propulsion motors only
	Differential protection or similar protection	√			√			For motors ≥ 1500 kW
Propulsion Semiconductor converter	Voltage (input)		√			√		
	Current (input)		√			√		
	Overload (high current)	√			√			Alarms before protective device is activated
	Open/close position for assignment switches					√		
	Converter cooling medium temperature – high	√	√		√	√		If applicable
	Failure of converter cooling pump or fan motor	√			√			If applicable
	Inter-phase reactor temperature – high				√	√		
	Tripping of filter circuit fuse	√			√			
Propulsion Transformer	Transformer windings temperature – high	√	√		√	√		

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Others	Field circuit earth fault	√			√			May be omitted in circuits of brushless excitation systems and of motors rated up to 500 kW
	Main propulsion circuit earth fault		√			√		

15.2.10.2 Ships having machinery notation(s) are to comply with the automatic control and monitoring requirements applicable to diesel engines and gas turbines of propulsion generating sets as well as main boilers and auxiliary steam turbines, as specified in PART SEVEN of the Rules. Where two or more propulsion generating sets are provided and 100% design speed is still achieved upon the shutdown of any of them, only the automatic control and monitoring requirements of PART SEVEN of the Rules for auxiliary diesel engines, auxiliary gas turbines and auxiliary steam turbines are to be complied with.

15.2.11 Special requirements for podded propulsion system

15.2.11.1 Where a ship is fitted with one or more podded propulsion units, the unit used as steering manoeuvring system is to be supplied and controlled in compliance with the requirements of 13.1.8, PART THREE of the Rules.

15.2.11.2 Where the electric motor is supplied by a slip ring, the following checks and tests on the ring are to be considered:

(1) check of the IP protection degree, in accordance with the location of the slip ring;

(2) check of clearances and creepage distances;

(3) check of contact resistance of the slip ring;

(4) endurance test: After the contact pressure and rated current are set, the slip ring is subjected to a rotation test. The number of rotations is evaluated taking into consideration the ship operation and rotation speed control system. The possibility of turning the pod 180° to proceed astern and 360° to return to the original position is to be considered. The ring may be submitted to cycles comprising full or partial rotation in relation to the use of the pod as steering gear. The voltage drops and current are to be recorded. An overload test is to be carried out (minimum 150%, 15s);

(5) check of the behaviour of the slip ring when subjected to the vibration described in IEC Publication 60068-2-6;

(6) check of the behaviour of the slip ring, after damp heat test, as described in IEC Publication 60068-2-30;

(7) after the damp heat test, an insulation resistance test is to be carried out;

(8) dielectric strength test.

15.2.11.3 All system failure alarms are to be displayed in the bridge. Alarms are to be arranged for the pod under the following circumstances:

(1) overload of propulsion motors;

(2) power failure of propulsion motors;

(3) low pressure of hydraulic oil system;

(4) low pressure of lubricating oil supply;

(5) high temperature of lubricating oil;

(6) low level of lubricating oil tank for motor bearings;

(7) high temperature of motor cooling air inlet;

(8) high temperature of motor cooling air outlet;

(9) abnormal operation of bilge pump;

(10) high level of pod bilge.

15.2.11.4 Sensors for control, monitoring and alarm systems located within the pod are to be duplicated, one acting as a standby for the other.

15.2.11.5 An effective cooling system is to be provided for the propulsion motor within the pod, and a standby cooling arrangement is to be provided and available for immediate use.

15.2.11.6 Two independent means of automatic bilge drainage are to be provided for the pod. The number and location of bilge level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

15.2.11.7 The pod connecting bolts and slewing ring bearings are to comply with recognized standards, as applicable.

15.2.12 Cooling and ventilation

15.2.12.1 Loss of ventilation to compartments with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other.

15.2.12.2 If semiconductor converters are separately cooled, the plant is to be capable of continuing operation at reduced power level if the cooling system fails. Means to contain any leakage of cooling liquid are to be provided so that the liquid does not cause a failure of the converter or any other electrical equipment located near the converter.

Section 3 STRUCTURAL REQUIREMENTS FOR PODDED PROPULSION UNITS

15.3.1 General requirements

15.3.1.1 Members of the hull support structure for a podded propulsion unit comprise a pedestal girder and its face plate (if fitted) that support the strut, and an orthotropic grillage of webs and floors that are connected to or surround the pedestal girder, as shown in Figure 15.3.1.1. This grillage may be of single or double bottom construction, but normally of double bottom in way of the podded propulsion unit.

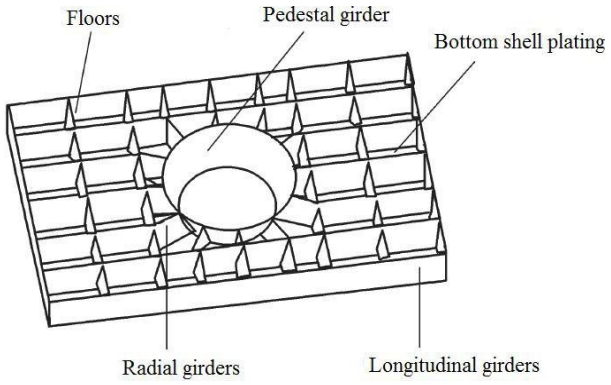


Figure 15.3.1.1

15.3.1.2 The outer ends of radial girders are generally to be connected to bottom longitudinal girders and floors and aligned with them both longitudinally and transversely, transferring the supported load to the hull structure. If the spacing of radial girders is too great, consideration is to be given to arranging supporting brackets between the slewing bearing outer races and pedestal girder to increase the rigidity of outer races. The thickness of the pedestal girder and its surrounding girders is not to be less than the minimum Rule thickness of solid floors or girders at the same positions. Where abutting plates are of dissimilar thickness, the applicable taper requirements of Chapter 2, PART TWO of the Rules are to be complied with.

15.3.1.3 In general, full penetration welding is to be applied in way of connections of the pedestal girder to the bottom shell plating and to the inner bottom plating or top outer races, and in way of the end connections between the radial girders and the pedestal girder. Radial girder webs are to be welded to the underside of the outer races at the top of the pedestal girder and its face plate, if fitted, is to be welded to the outer side of such outer races. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0.34.

15.3.1.4 The hull support structure is to be able to withstand the maximum loads transferred from the strut of podded propulsion unit and is to be sufficiently stiff that any deformation as a consequence of the maximum loads will not exceed the limits required for slewing bearing operation. The limits are to be based on the operational requirements for the pod.

15.3.1.5 The arrangement of the hull support structure and scantlings of its primary members are subject to direct strength analysis according to the following requirements:

(1) The support structure is to be modelled (e.g. elements and mesh size, etc.) by regular means of hull structure direct calculation, and the boundary conditions are to be obtained on the principle that response consequences of the members for assessment are not affected.

(2) Loads are to be provided by the pod manufacturer/designer, generally taking into consideration normal and ultimate conditions of the podded propulsion unit (see Note ① of Table 15.3.1.5).

(3) The calculated stress of the structural member is not to be greater than the permissible value. The permissible stress value is obtained by the material yield strength divided by the corresponding safety factor given in Table 15.3.1.5.

Safety Factor **Table 15.3.1.5**

Condition / Stress type	Normal condition	Ultimate condition
Normal stress	1.67	1.50
Shear stress	2.50	2.25
Equivalent Von Mises stress of plate elements	1.43	1.33

Notes:

① Normal condition means the normal operation condition, in which the structure does not fail while the ship is in normal service; ultimate condition means the most critical condition, in which the structure is subject to the maximum load expected due to accident.

② For check of the equivalent Von Mises stress of plate elements, only the equivalent stresses at the mid plane (membrane) at the element centroid are to be considered. However, high stress due to poor-shape elements may not be considered.

③ The safety factor for a plate element directly connected to the pedestal and located at the corner of a three-dimensional intersection may be appropriately reduced, but not to be less than 1.1. Where refined mesh analysis is applied here, the stress value of the element may be deducted by 5%.

15.3.1.6 In addition, scantlings of primary members are not to be less than those required for the stern structure in PART TWO of the Rules, as applicable.

CHAPTER 16 MEASUREMENT OF VIBRATION AND NOISE

Section 1 GENERAL PROVISIONS

16.1.1 General requirements

16.1.1.1 This Chapter applies to ships of 65 m or over in length applying for the class notations G-ECO,G-ECO VIBx and Gd-ECO NOIx specified in ISC Rules for Green Eco-Ships.

Section 2 NOISE

16.2.1 General requirements

16.2.1.1 Noise is to meet the requirements of Chapter 2, 2.2.1.1(3), 2.5.2 and Chapter 4, 4.3.2 of ISC Rules for Green Eco-Ships. Noise measurements are to be carried out in accordance with the requirements of Section 4.

Section 3 VIBRATION

16.3.1 General requirements

16.3.1.1 Vibration is to meet the requirements of Chapter 2,2.5.1 and Chapter 4, 4.3.1 of ISC Rules for Green Eco-Ships. Vibration measurements are to be carried out in accordance with the requirements of Section 4.

Section 4 MEASUREMENTS AND REPORTS

16.4.1 General requirements

16.4.1.1 The measurements of noise and vibration may be undertaken by ISC or an organization accepted by ISC. The measurements are to be witnessed by a ISC Surveyor.

16.4.2 Instrumentation

16.4.2.1 The vibration measurement and calibration equipment is to comply with ISO 6954:2000 and ISO 8041, and the instrumentation is to include at least a transducer with an appropriate amplifier, and a FFT analyser.

16.4.2.2 The instrumentation used is to be within a calibration validity period specified by the calibration authority, and copies of relevant documents are to be provided prior to measurements and together with the measurement report.

16.4.3 Test conditions for measurements

16.4.3.1 Prior to measurements, a measurement procedure is to be submitted to ISC for approval. This procedure is at least to contain details of the arrangement of measuring points, loading condition, weather condition, machinery operating condition, and measuring equipment. ISC may require additional measurements at the measuring points or locations.

16.4.3.2 Possible deviation from the required conditions may be accepted by ISC and this is to be clearly mentioned in the report.

16.4.3.3 Tests are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

16.4.3.4 Generally the main engine is to operate with the power output corresponding to the designed normal seagoing condition, or at least 80% of the maximum continuous power available. All machineries and equipment that may operate simultaneously under normal operation conditions are to be run simultaneously.

16.4.3.5 In general, the tests are to be conducted in deep water, with a water depth not less than 5 times the mean draft and a distance from shore not less than 25 times the ship breadth. For ships usually

operating in shallow waters, the tests are to be performed with conditions corresponding to normal service conditions.

16.4.3.6 The tests are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code, with the wind force being not greater than 4 on the Beaufort scale.

16.4.3.7 Tests may generally be conducted in sea trial conditions. For cargo ships which may be operated over a large range of drafts, if the designed normal seagoing condition is different from the test conditions, additional measurements may be required.

16.4.3.8 Ship course is to be kept constant as far as possible, with rudder angle variations being within the range of ±2 degrees portside or starboard, for the duration of the measurement.

16.4.3.9 For offshore service ships to be operated at DP, measurements are to be carried out with the side thrusters in an operating condition corresponding to contractual conditions or with at least 40% power on the thrusters.

16.4.4 Vibration measurements

16.4.4.1 Vibration measurements are to be conducted in accordance with ISO 6954:2000 and ISO 20283-2.

16.4.4.2 Measurement locations are to be chosen so that the assessment represents the overall vibration environment on board the ship. In cabins, vibration readings are to be taken in the centre of the floor area. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

16.4.4.3 The vibration measurement report is to comply with ISO 6954:2000 and ISO 20283-2, containing measurement positions and directions indicated on a general arrangement plan, tabulated vibration levels, ship and machinery details, test conditions, and copies of the relevant instrument calibration certificates.

CHAPTER 17 ADDITIONAL REQUIREMENTS FOR GEOTEXTILES LAYERS

Section 1 GENERAL PROVISIONS

17.1.1 Application

17.1.1.1 This Chapter applies to ships provided with special equipment for laying geotextiles.

17.1.1.2 Geotextiles layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of ISC Rules for Materials and Welding and of the flag State Administration, if any.

17.1.2 Notation

17.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Geotextiles Layer.

17.1.3 Definition

17.1.3.1 Geotextiles layers mean ships provided with special equipment for laying geotextiles, which are engaged in operations of laying soft mattress related to construction of cofferdams on land and floating structure projects under different environmental conditions such as coastal shoals and deep-water harbors.

17.1.4 Plans and documents

17.1.4.1 In addition to the plans and documents required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to ISC for approval (where applicable):

(1) Plan of reinforcement structure of geotextiles laying turning plate equipment;

(2) Plan of reinforcement structure of geotextiles laying positioning equipment.

17.1.4.2 The following plans and documents are to be submitted to ISC for information (where applicable):

(1) Information related to geotextiles laying equipment (such as turning plate, guide beam, coil drum and crane, etc.);

(2) Strength calculations of reinforcement structure of geotextiles laying equipment;

(3) Arrangement plan of positioning equipment of geotextiles laying operation;

(4) Strength calculations of reinforcement structure of geotextiles laying operation.

For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by ISC.

Section 2 HULL STRUCTURE AND ARRANGEMENT

17.2.1 Hull structure

17.2.1.1 For hull structural strength, consideration is to be given to necessary reinforcement of the support structure of the equipment used in geotextiles laying operation.

17.2.2 Requirements for the support structure of geotextiles laying equipment

17.2.2.1 The strength of support and reinforcement structure of geotextiles laying equipment and geotextiles laying operation positioning equipment is to be checked by referring to the relevant requirements of Section 7, Chapter 3, PART TWO of the Rules.

17.2.3 Bunker

17.2.3.1 The bunker cannot be directly positioned under the working deck, unless a void hold or ballast tank etc. is arranged between the working deck and the bunker.

17.2.4 Hold arrangement

17.2.4.1 The working deck is to be distant from the engine room air inlet and outlet as far as possible.

Section 3 EQUIPMENT

17.3.1 General provisions

17.3.1.1 Geotextiles layers are to be capable of anchor mooring positioning or dynamic positioning.

17.3.2 Wheel house

17.3.2.1 A geotextiles layer is to be provided with a wheel house with good vision or a 360 ° video system for the whole ship, and communication by means of hardwired connection between the wheel house and the remote control station is to be provided.

CHAPTER 18 ADDITIONAL REQUIREMENTS FOR HEAVY EQUIPMENT CARRIER

Section 1 GENERAL PROVISIONS

18.1.1 Application

18.1.1.1 This Chapter applies to the carriers having larger deck areas and specially engaged in loading/unloading on decks and long-distance transporting the complete sets of heavy equipment and project facilities with the larger dimension/weight such as bridge cranes and heavy equipment at sea (hereinafter called the heavy equipment carriers).

18.1.1.2 The designer is to carry out the calculation and verification for longitudinal strength and the strength of deck and supporting structure below according to the heavy equipment intended to carry and submit the calculation information to ISC for information.

18.1.1.3 Besides the applicable requirements in this Chapter and the other Parts of the Rules as well as the ISC Rules for Materials and Welding, the heavy equipment carriers are to comply with the relevant provisions of the Administrations of flag States.

18.1.1.4 Where it complies with the requirements of this Chapter, the heavy equipment carrier may be assigned to the class notation of:

Bridge Crane and Heavy Equipment Carrier

Section 2 OUTFITTINGS

18.2.1 Equipment number

18.2.1.1 The equipment number for heavy equipment carriers is to comply with the requirements of 3.2.1 in Chapter 3 of PART TWO of the Rules, the total lateral windward area of the designed maximum complete sets of heavy equipment and project facilities is to be taken into consideration in the calculation of equipment number. Where such lateral windward area of the heavy equipment and project facilities can not be provided, the equipment number may be taken by increasing two grades.

18.2.2 Securing

18.2.2.1 The securing for the heavy equipment carriers carrying complete sets of heavy equipment and project facilities is to meet the requirements of ISC Guidelines for the Preparation of the Cargo Securing Manual. It may be acceptable that the ship's dynamic load is obtained by the seakeeping characteristics analysis and quasi-static force analysis under the worst sea conditions occurred possibly through the recognized software.

Section 3 INTACT STABILITY

18.3.1 Intact stability

18.3.1.1 The intact stability of heavy equipment carriers is to meet the requirements for dry cargo ships of the flag State Administrations.

18.3.1.2 The streamlined reduction is not to be considered when the wind area of complete sets of heavy equipment and project facilities is calculated, however, the lateral overlapping area may be deducted.

Section 4 SPECIAL REQUIREMENTS FOR EXTRA BALLAST OPERATION

18.4.1 General requirements

18.4.1.1 Extra ballast operation for heavy equipment carrier means:

(1) an operational condition for a ship with the draft not exceeding operational draft mark during the ballasting operation in order to load/unload the complete sets of heavy equipment and project facilities at port; and
(2) ship shifting at port with restrictions such as passing through bridge, etc., under the ballast condition of (1).
18.4.1.2 The extra ballast operation may be carried out provided that the heavy equipment carrier meets the requirements of this Section. The implementation of extra ballast operation is to be in compliance with the requirements of Extra Ballast Operational Procedure Manual in Section 5 of this Chapter.
18.4.1.3 During the extra ballast operation, the heavy equipment carrier is also to be in accordance with the following restricted meteorological/sea conditions:
(1) Beaufort scale not exceeding 5 for the extra ballast operation mentioned in 18.4.1.1(1);
(2) Beaufort scale not exceeding 4 and at the normal calm sea area (significant wave height less than 0.3 m) for the extra ballast operation mentioned in 18.4.1.1(2).
18.4.1.4 In order to ensure the ship draft and floating condition meet the relevant requirements during its extra ballast operation, ship draft meter is to be provided onboard and capable of indicating the forward draft, aft draft and amidship draft in the bridge.

18.4.2 Operational draft mark

18.4.2.1 Where the ship is ballasted to the maximum draft, the ratio between reserve buoyancy under freeboard deck and displacement at the draft is not to be less than 15%.
18.4.2.2 The maximum draft waterline mark which is allowable under extra ballast operation is to be assigned at the ship's both sides, refer to Figure 18.5.2.5 in Section 5 of this Chapter. The maximum extra ballast waterline mark is a horizontal line 400 mm in length and 25 mm in breadth. The upper edge of the line is to be in line with the maximum draft waterline and marked the letters of EB of 115 mm in height and 75 mm in width to indicate the extra ballast operational draft at both ends above the line.
18.4.2.3 Before the maximum draft waterline mark of extra ballast operation for heavy equipment carrier is assigned, it is to be verified that the requirements of reserve buoyancy, stability and strength of this Section have been met and marked in the Extra Ballast Operational Procedure Manual.

18.4.3 Intact stability and floating condition

18.4.3.1 The maximum angle of heel during the loading/unloading of complete set of heavy equipment and project facilities is not to exceed the following:
(1) where the ship affects the action of beam wind evenly with the load of 0.22 kPa (speed of 18 m/s), the angle of heel is not to exceed the emerging angle of freeboard deck edge, the level of wind moment is to be measured to the half draft from the centroid of wind area, for calculation, the wind area of complete set of heavy equipment and project facilities is to be in accordance with the requirement of 18.3.1.2 of this Chapter;
(2) 12°, whichever is the less.
18.4.3.2 The elements of each ballasting step under ship's extra ballast condition as corrected for free surface are to comply with the following:
(1) where the ship affects the action of beam wind evenly with the load of 0.22 kPa (speed of 18 m/s), the angle of heel is not to exceed the emerging angle of freeboard deck edge, the level of wind moment is to be measured to the half draft from the centroid of wind area, for calculation, the wind area of complete set of heavy equipment and project facilities is to be in accordance with the requirement of 18.3.1.2 of this Chapter;
(2) the initial metacentric height (GM) is not to be less than 0.5 m;
(3) the positive range of righting lever (GZ) curve is not to be less than 15°;
(4) the area under the righting lever (GZ) curve up to the angle of maximum GZ is not to be less than 0.035 m·rad.

18.4.4 Structural strength

18.4.4.1 The hull longitudinal strength under extra ballast condition is to meet the requirements of Longitudinal Strength in Section 2 of Chapter 2, PART TWO of the Rules, in which the wave load of hull beam is to be determined by direct calculation, or is obtained as 40% of the value calculated according to the formula in 2.2.3 of Section 2 in Chapter 2, PART TWO of the Rules.
18.4.4.2 The local strength of hull structure under extra ballast condition is to be verified.

Section 5 EXTRA BALLAST OPERATIONAL PROCEDURE MANUAL

18.5.1 General requirements

18.5.1.1 The purpose of Extra Ballast Operational Procedure Manual is to indicate that the ship meets with the requirements of extra ballast operation types and operational draft mark, stability and strength and provide the operational procedure and specification which the implementation for extra ballast operation – filling and discharging the ballast water is to be complied with to the master.

18.5.1.2 The Extra Ballast Operational Procedure Manual is to be submitted to ISC for approval.

18.5.2 Contents of the Extra Ballast Operational Procedure Manual

18.5.2.1 The initial condition of ship before extra ballast operation includes:

(1) loading conditions of complete sets of heavy equipment and project facilities, including the datum such as quantity, location, weight and center of gravity;

(2) datum such as quantity, location, weight and center of gravity of consumables carried onboard the ship;

(3) datum such as quantity, location, weight and center of gravity of ballast water loaded onboard the ship.

18.5.2.2 Steps for ballast operation such as filling of ballast water under full-loaded arrival condition are as follows:

Initial condition:

(1) loading condition of complete sets of heavy equipment and project facilities……

(2) condition of consumables carried onboard the ship……

(3) loading condition of ballast water……

Each steps of extra ballast operation:

(1) Step 1……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

(2) Step 2……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

(3) Step 3……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

18.5.2.3 The stability and strength calculation for steps specified in 18.5.2.2 of this Section for each operation mentioned in 18.5.1.1 of this Section is to be given as Tables 18.5.2.3(1) and 18.5.2.3(2):

Stability and Strength Calculation for Each Step of Extra Ballast Operation during Loading/Unloading of Complete Sets of Heavy Equipment and Project Facilities at Port

Table 18.5.2.3(1)

Loading Condition ID	Exps 0	Exps 1	Exps 2	Exps 3	……
Ballast steps	Step 0	Step 1	Step 2	Step 3	……
Displacement (t)					……
MAX. BM (kN·m)					……
Location of MAX. BM					……
MAX. SF (kN)					……
Location of MAX. SF					……
Draft at LCF (m)					……
Draft at AP (m)					……
Draft at FP (m)					……
Mean draft (m)					……
Trim (m)					……
VCG (m)					……
Corrected GM (m)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)
MAX. GZ (m)					
Heel at MAX. GZ (deg)					
Area under GZ curve up to heel at MAX. GZ (m·rad)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)
Reserve Buoyancy (%)	(> 15)	(> 15)	(> 15)	(> 15)	(> 15)
Positive stability range (deg)	(> 10)	(> 10)	(> 10)	(> 10)	(> 10)

Stability and Strength Calculation for Each Steps of Extra Ballast Operation during Shifting of Ship Carried with Complete Sets of Heavy Equipment and Project Facilities

Table 18.5.2.3(2)

Loading Condition ID	Bdg 0	Bdg 1	Bdg 2	Bdg 3	……
Ballast steps	Step 0	Step 1	Step 2	Step 3	……
Displacement (t)					……
MAX. BM (kN·m)					……
Location of MAX. BM					……
MAX. SF (kN)					……
Location of MAX. SF					……
Draft at LCF (m)					……
Draft at AP (m)					……
Draft at FP (m)					……
Mean draft (m)					……
Trim (m)					……
VCG (m)					……
Corrected GM (m)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)
MAX. GZ (m)					
Heel at MAX. GZ (deg)					
Area under GZ curve up to heel at MAX.GZ (m·rad)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)
Reserve Buoyancy (%)	(> 15)	(> 15)	(> 15)	(> 15)	(> 15)
Positive stability range (deg)	(> 10)	(> 10)	(> 10)	(> 10)	(> 10)

18.5.2.4 The format table of capacity of ballast tank is given in Table 18.5.2.4:

Table of Capacity of Ballast Tank **Table 18.5.2.4**

No.	Compartment	Frame No.	Capacity (m^3)	LCG (m)	TCG (m)	VCG (m)	F.S.I. (m^4)
1							
…							

18.5.2.5 The sketch of maximum draft waterline mark (starboard) is given in Figure 18.5.2.5:

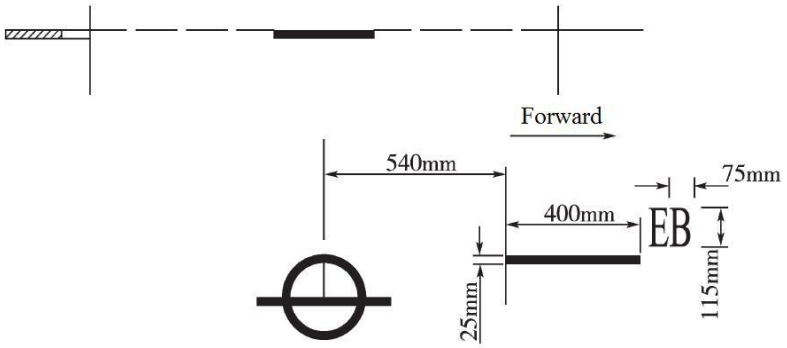


Figure 18.5.2.5 The Sketch of Maximum Draft Waterline Mark (starboard)

where: EB means the extra ballast.

CHAPTER 19 AC SHORE CONNECTION SYSTEMS

Section 1 GENERAL PROVISIONS

19.1.1 General requirements

19.1.1.1 This Chapter applies to AC shore connection systems with rated voltages (voltage between phases) of 15 kV or less for power supply to ships in port. Such systems are capable of transferring load between the shore supply and the ship's electrical power via blackout or temporary parallel running.

19.1.1.2 Guidelines for operations of shore connection are to be developed for ships to ensure operational safety for shore connection.

19.1.1.3 Where an HVSC system is arranged otherwise than specified in this Chapter, consideration may be given by ISC to acceptance of such arrangement, provided that it achieves an equivalent safety level.

19.1.1.4 During shore supply, proper measures are to be taken to avoid and minimize any harm to the safety of the ship and its personnel due to loss of electrical power.

19.1.1.5 The shipside installations fitted in areas where flammable gas or vapour and/or combustible dust may be present are to be certified safe type as suitable for the flammable gas or vapour and/or combustible dust encountered, otherwise they are to be prohibited from being used.

19.1.1.6 A compatibility assessment is to be performed to verify the possibility to connect the ship to shore supply prior to the first arrival at a terminal, taking into account the compatibility of voltage, frequency, capacity and short-circuit current of the shore supply.

19.1.2 Class notation and product certificate

19.1.2.1 Ships fitted with shipside installations for HVSC systems and complying with the requirements of this Chapter may be, upon request, approval of drawings, survey and testing, assigned by ISC the following class notation: AMPS (AMPS: Alternative Maritime Power Supply). The maintenance, suspension, cancellation and reinstatement of the class notation are to be in compliance with Section 9, Chapter, PART ONE of the Rules.

19.1.2.2 Shipside installations for HVSC systems will be, upon survey, issued by ISC appropriate product certificates.

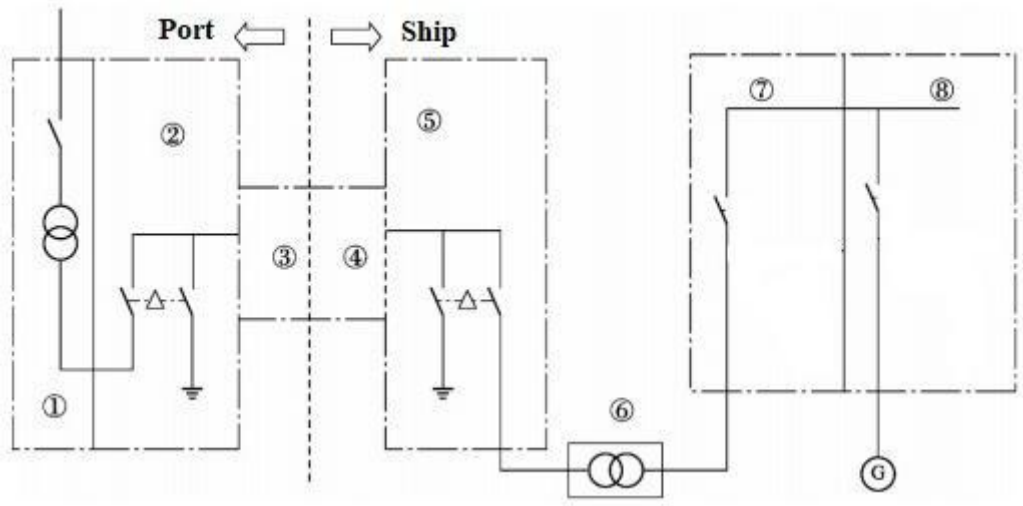
19.1.3 Definitions and terms

19.1.3.1 For the purpose of this Chapter, the following definitions apply:

(1) An **AC shore connection system** is the equipment used for power supply to ships in port, consisting of shipside and shore installations.

(2) An **AC low voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of 1 kV or less for power supply from port (shore supply) to ship's power distribution system.

(3) An **AC high voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of shore supply to ship's distribution system from 1 kV up to and including 15 kV. A typical AC HVSC system is shown in Figure 19.1.3.1(3).



① HV shore supply system (including transformers); ② HV shore distribution box; ③ Shore connection socket box; ④ Cable management system and cables (with plugs); ⑤ Shore connection switchboard; ⑥ Transformer; ⑦ Shore receiving control panel; ⑧ Generator panel of main switchboard

Figure 19.1.3.1(3) Diagram of a Typical AC High Voltage Shore Connection System

(4) **Shipside installations** are the equipment fitted on the ship for connection to shore supply, generally consisting of plugs/sockets, shore connection switchboards, transformers, shore receiving control panel (usually integrated into the main switchboard), shore connection cables and a cable management system.
(5) **Shore installations** are the equipment fitted at a terminal or port and used for power supply to ships, generally consisting of an HV shore distribution box, transformers, frequency converters (if applicable) and a shore connection socket box.
(6) A typical **cable management system** consists of cable winches, automatic controls of cable length or tension together with associated instrumentation. The ship's shore connection cables are picked and laid through the cable management system for connection to shore supply.
(7) **Equipotential bonding** provides electric connections between conductive parts, intended to achieve equipotentiality.

19.1.4 Drawings and information

19.1.4.1 Drawings and information specified in 19.1.4.2 and 19.1.4.3 of this Chapter are to be submitted to ISC for approval.
19.1.4.2 The following drawings and information for ship system are to be submitted for approval:
(1) Estimation of loads under shore connection;
(2) Evaluation of short-circuit currents under shore connection (applicable to ships provided with AC high voltage shore connection systems, and ships provided with AC low voltage shore connection systems for which short circuit current calculations are submitted in accordance with requirements of 1.1.3.1(2) of PART FOUR of the Rules);
(3) Drawing of the electrical system of shipside installations;
(4) Arrangement of shipside installations;
(5) Mooring test program for HVSC system (to be submitted to the ISC attending surveyor for review).
19.1.4.3 The following drawings and information for marine products of shipside installations of HVSC system are to be submitted for approval:
(1) Technical specifications of the system;
(2) Switchboards (including shore connection switchboard, transformer cabinet (if fitted), shore receiving control panel):
① electrical schematic diagram;
② list of components;
③ structural drawing (including external size, housing material, housing structure, coating, layout of faceplate, internal arrangement, rating plate, nameplate);
(3) Details of plugs/sockets;
(4) Details of shore connection cables;

(5) Details of cable management system;
(6) Test programs for the above equipment.
19.1.4.4 The following information are to be submitted to ISC for reference:
(1) Technical instructions of the system (for drawing approval of both ship and marine products);
(2) Instructions for fitting, using and maintenance (for drawing approval of marine products);
(3) List of system equipment (for drawing approval of marine products).

Section 2 SYSTEM DESIGN

19.2.1 General requirements

19.2.1.1 The AC shore connection system is to have a capacity sufficient for ensuring expected services (including emergency services) normally required for the ship while in port.
19.2.1.2 An equipotential bonding between the ship and the shore is to be established, and this bonding is not to change the earthing principle of the ship's power distribution system.
19.2.1.3 During shore supply, at least one of the ship's main generators is to be standby and, upon blackout of the shore supply, automatically started and connected to the main switchboard.

19.2.2 Emergency shutdown

19.2.2.1 Emergency shutdown facilities are to be provided to ensure instantaneously opening shore connection circuit breakers on shore and on board the ship. The emergency shutdown facilities are to be designed according to the fail-safe principle and so arranged as to prevent inadvertent activation.
19.2.2.2 The emergency shutdown facilities are to be activated automatically in any of the following cases:
(1) loss of equipotential bonding (applicable to AC high voltage shore connection system);
(2) alarm signal from the cable management system (mechanical stress of cable is too high, or remaining cable length is too short);
(3) loss of any control and monitoring circuits of HVSC system;
(4) disengaging of power plugs from any socket while the connection is live.
19.2.2.3 Emergency stop buttons that activate emergency shutdown facilities are to be provided at least at:
(1) the location of the shore connection switchboard;
(2) the position of operation of the cable management system;
(3) the location of the shore receiving control panel.
19.2.2.4 Activation of the emergency shutdown is to result in an audible and visual alarm at a manned location① of the ship in port.
19.2.2.5 Following the emergency shutdown, the circuit breaker is not to be closed until reset manually.

19.2.3 Safety interlocking

19.2.3.1 For the AC high voltage shore connection system, an earthing switch complying with the requirements of 5.3 of IEC 62271-200 is to be provided at the end of shore connection cable on board. While the shore connection circuit breakers are in the open position, the conductors of the cables are to be kept earthed by the earthing switch.
19.2.3.2 Arrangements are to be provided so that the shore connection circuit breaker (fitted in the shore connection switchboard) cannot be closed or automatically opened from its closed position in any of the following cases:
(1) equipotential bonding is not established (applicable to AC high voltage shore connection system);
(2) the pilot contact circuit of shore connection plugs/sockets is not established②;
(3) emergency shutdown facilities are activated;
(4) loss of any control and monitoring circuits of HVSC system;
(5) alarm signal from the cable management system (tension level of cable is too high, or remaining cable length is too short);
(6) earth fault on the ship's distribution system (applicable to AC high voltage shore connection system);
(7) the shore supply is not present.

19.2.4 Cable management system

---

① The location of the on-duty operator of shore connection as specified in the Guidelines for operations of shore connection.
② The connection is established by proper contact of the pilot contactors embedded in the plug and socket.

19.2.4.1 A cable management system is to be provided for shore connection cables to ensure that:
(1) the mechanical tension applied to the cables will not exceed the designed permissible value;
(2) the possibility of transmitting mechanical stresses to cables or terminals is excluded;
(3) the shore connection circuit breaker will be instantaneously opened where cables are excessively extended.

19.2.5 Load transfer

19.2.5.1 Load transfer between the shore supply and the shipstantaneously opened where cabcuted via blackout or temporary parallel running.
19.2.5.2 Where load transfer is executed via blackout, means are to be provided to prevent simultaneous supply from the ship's generators (including emergency ones) and the shore supply.
19.2.5.3 Where load transfer is executed via temporary parallel running of the shipboard generator and the shore supply, compliance of voltage and frequency variations with the requirements of 1.2.2, Chapter 1, PART FOUR of the Rules is to be ensured.
19.2.5.4 The temporary running in parallel is also to comply with the following requirements:
(1) Means are to be provided for automatic synchronization of the shipboard generator and the shore supply.
(2) Load transfer is to be automatic.
(3) The duration of the temporary parallel running is to be as short a period as practicable allowing for the safe transfer of the load.
(4) If the defined transfer time limit for load transfer is exceeded, the transfer is to be stopped, shore connection circuit breakers are to be opened, and an audible and visual alarm is to be activated at a manned location.

19.2.6 Short-circuit protection

19.2.6.1 Where only the shore supply is used, the short-circuit current calculation is to be referred to ISC guidance document GD021-1999 Calculation of Short-Circuit Current Fed through AC Shore Power System or other methods acceptable to ISC. For temporary parallel running of the shore supply and the ship's electrical power, the short-circuit current calculation is to be referred to IEC 60909 publications or other methods acceptable to ISC.
19.2.6.2 During shore supply, the prospective short-circuit current level at any point in the ship's power distribution system is not to exceed the short-circuit breaking and making capacities of circuit breakers installed onboard.
19.2.6.3 For assessment of short-circuit currents, the prospective short-circuit current level for both the shore supply and the ship's electrical power are to be taken into account. Consideration may be given to the following measures for restricting prospective short-circuit currents during connection to shore supplies:
(1) preventing parallel connection of shore supplies with the ship's sources of electrical power; or
(2) restricting the number of the ship's generating sets operating during parallel connection to transfer load; and/or
(3) restricting the short-circuit current level from shore supply to the ship's power distribution system.

Section 3 ELECTRICAL EQUIPMENT

19.3.1 General requirements

19.3.1.1 In addition to the requirements of this Chapter, shipside installations of the AC high voltage shore connection system are to comply with the requirements of 2.14.2.3, 2.14.2.4, 2.14.4, 2.14.6 and 2.14.7 of Chapter 2, PART FOUR of the Rules.
19.3.1.2 Equipment with voltage above 1 kV is not to be installed in the same enclosure with low voltage equipment, unless segregation or other suitable means are provided to ensure that access to low voltage equipment is obtained without danger.
19.3.1.3 In addition, shipside installations are to be arranged to prevent interference with the ship's mooring and cargo handling operations.
19.3.1.4 The degrees of protection provided by enclosures for components of shipside installations are to be appropriate to the location where they are situated, and comply with the requirements of 1.3.2.2 of Chapter 1 and 2.14.2.2 of Chapter 2, PART FOUR of the Rules.

19.3.2 Shore connection switchboard

19.3.2.1 The shore connection switchboard of the AC high voltage shore connection system is to be in

accordance with the publication IEC 62271-200, service continuity LSC1.

19.3.2.2 The shore connection switchboard is to be located as close as possible to shore connection cables on board.

19.3.2.3 The switchboard is to include a circuit-breaker for protection against undervoltage, overvoltage and short-circuit current.

19.3.2.4 The shore connection switchboard is to be fitted with the following instruments, indicators and alarms:

(1) one voltmeter: all three phases;
(2) one ammeter: all three phases;
(3) one frequency meter;
(4) one kilowatt-hour meter (optional);
(5) shore power indicator: power connected;
(6) circuit breaker tripping with alarm;
(7) earth-fault alarm (applicable to AC high voltage shore connection system);
(8) phase rotation indicator.

19.3.2.5 Where measures for restricting short-circuit currents are taken as required in 19.2.6.3(3), a corresponding device is to be provided in the shore connection switchboard.

19.3.3 Shore receiving control panel

19.3.3.1 The shore receiving control panel is to be in accordance with the applicable requirements in Section 3, Chapter 3, PART FOUR of the Rules.

19.3.3.2 The shore receiving control panel is in general to be a component of the main switchboard, which is to be provided with isolation switches or circuit breakers.

19.3.3.3 The shore receiving control panel is to be fitted with the following instruments:

(1) two voltmeters[①]: 1 for measuring the voltage in each phase of the shore supply, 1 for measuring the busbar voltage;
(2) one ammeter: all three phases of the shore supply;
(3) two frequency meters[①]: 1 for measuring the frequency of the shore supply, 1 for measuring the bus-bar frequency;
(4) phase rotation indicator;
(5) synchronizing device.

19.3.4 Transformers

19.3.4.1 Transformers are to be of the separate winding type for primary and secondary sides and comply with the applicable requirements of the series publications IEC 60076.

19.3.5 Cables

19.3.5.1 High voltage shore connection cables are to comply with the requirements of Annex A of the publication IEC 80005-1 or other acceptable standards. Low voltage shore connection cables are to comply with the requirements of Annex A of the publication IEC80005-3 or other acceptable standards.

19.3.5.2 Fixed high voltage cables on board are to comply with the requirements of publications IEC 60092-353 and IEC 60092-354 or other equivalent standards.

19.3.6 Plugs and socket outlets

19.3.6.1 The ship may be connected to the shore supply via suitable means or plugs and socket outlets. Plugs and socket outlets are to be designed so that an incorrect connection cannot be made and that plugs cannot be inserted or withdrawn while live. Plugs and socket outlets are to be in accordance with international[②] and/or national standards.

---

① Where the shore supply is connected to the bus bar and the voltage and frequency of the bus bar are easy to observe for the operator, only one voltmeter and one frequency meter may be fitted.

② For the standards for AC high voltage shore connection systems, refer to IEC 62613-1, Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC systems) – Part 1: General Requirements and IEC 62613-2, Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC systems) – Part 2: Dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships. For the standards for AC low voltage shore connection systems, refer to IEC 60309-1, Plugs, socket-outlets and couplers for industrial purposes – Part 1: General Requirements, IEC 60309-2, Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories and IEC 60309-5, Plugs, socket-outlets and couplers for industrial purposes – Part 5: Dimensional compatibility and interchangeability requirements for plugs, socket-outlets, ship connectors and ship inlets for low-voltage shore connection systems (LVSC).

Section 4 SURVEY AND TESTING

19.4.1 Inspections and tests of products

19.4.1.1 Shipside installations and their components are to be certified by ISC in accordance with Chapter 3, PART ONE of the Rules.

19.4.1.2 Components of shipside installations are to be inspected and tested according to approved drawings and relevant standards.

19.4.2 Ship surveys

19.4.2.1 The first survey of shipside installations after fitting onboard new ships or ships in service is to be carried out in accordance with 19.4.2.2 of this Chapter, and the subsequent surveys are to be carried out in accordance with 19.4.2.3 and 19.4.2.4 of this Chapter.

19.4.2.2 Initial survey

(1) Check of product certificates of shipside installations.

(2) Check of compliance of the arrangement and fitting of shipside installations with approved drawings.

(3) The installations are to be subjected to the following inspections and tests:

① visual examination;

② test of insulation resistance to earth;

③ voltage withstand test of high voltage cable installation (applicable to AC high voltage shore connection systems, refer to 2.14.7.2(6) of Chapter 2, PART FOUR of the Rules;

④ functional tests, including overcurrent protection test of the connected breakers, test of phase rotation, test of emergency shutdown facilities, test of safety interlocking, test of load transfer in parallel (if applicable);

⑤ measurement of insulation resistance in hot condition;

⑥ functional test of cable management system.

19.4.2.3 Annual survey

(1) Shipside installations are to be subjected to the following tests:

① visual examination;

② test of insulation resistance to earth;

③ if practicable, the connection to shore supply may be tested for shore-to-ship power supply. Where such test is impracticable, the availability of the equipment is to be confirmed by examining the records of shore supplies and/or the records of maintenance of shipside installations.

19.4.2.4 The requirements for intermediate survey are the same as those for annual surveys.

19.4.2.5 Special surveys include, in addition to the annual survey items, functional tests as required in 19.4.2.2(3)④ of this Section and functional test of cable management system as required in 19.4.2.2(3)⑥ of this Section.

CHAPTER 20 ADDITIONAL REQUIREMENTS FOR ANCHOR HANDLING

Section 1 GENERAL PROVISIONS

20.1.1 Application

20.1.1.1 The requirements of this Chapter apply to anchor-handling ships.

20.1.2 Class notation

20.1.2.1 Ships complying with the requirements of this Chapter will be assigned the following class notation:

(1) Anchor Handling.

20.1.3 Plans and documents

20.1.3.1 The following plans are to be submitted for approval:

(1) Foundation and supporting structure of anchor handling winch;

(2) Stern rollers, towing pins, shark jaws and their supporting structures;

(3) Stability booklet (additional requirements for anchor handling);

(4) Construction profile and shell expansion.

20.1.3.2 The following plans or documents are also to be submitted for information:

(1) Arrangement of anchor handling equipment;

(2) Type and rated parameters of the anchor handling winch.

Section 2 HULL STRUCTURE

20.2.1 General requirements

20.2.1.1 Where not provided in this Chapter, the hull structure of anchor-handling ships is to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

20.2.2 Shell plating

20.2.2.1 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas is to be suitably reinforced. Where an anchor-handling ship is not provided with any fender, the thickness of shell plating is not to be less than that required in Section 3, Chapter 2, PART TWO of the Rules and not to be less than 11 mm.

20.2.3 Deck plating

20.2.3.1 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness. Where an anchor handling ship is an offshore supply ship, the increased thickness of deck plating is not to be less than 2 times that required by 11.3.2.1, Section 3, Chapter 11, PART TWO of the Rules.

20.2.3.2 Where the anchor and chain are kept on the deck, effective means (e.g. wooden sheathing) are to be provided to uniformly distribute their weight on the deck.

Section 3 ANCHOR HANDLING EQUIPMENT AND SUPPORTING STRUCTURES

20.3.1 Anchor handling arrangement

20.3.1.1 The following equipment is to be provided on anchor-handling ships:

(1) anchor handling winches;

(2) stern rollers;

(3) shark jaws;

(4) towing pins.

20.3.1.2 Anchor handling winches are to be designed in such a way as to allow an emergency release in

all operating conditions, and this is to be operable from the navigation bridge. After an emergency release, the braking of winches is to be capable of being restored to normal function immediately.

20.3.2 Equipment and supporting structures

20.3.2.1 The anchor handling winch and associated accessories are to be capable of sustaining the maximum load from the hoisting, rendering and braking including any dynamic loads as applicable without permanent deformation.

20.3.2.2 The foundation and supporting structures of anchor handling winches are to be capable of sustaining the maximum braking load or 1.5 times the maximum hoisting load, whichever is greater. The considered stress is not to be greater than the following permissible values:

normal stress $[\sigma] = 0.9R_{eH}$;

shear stress $[\tau] = 0.5R_{eH}$;

equivalent stress $[\sigma_e] = 1.0R_{eH}$;

where: R_{eH} is yield stress of material, in N/mm^2.

20.3.2.3 Stern rollers, shark jaws and towing pins are to be sized such that they, together with their supporting structures, are capable of sustaining 2 times the maximum static working load in all conditions of their arrangement, and the permissible stress under consideration is to be in accordance with 20.3.2.2 of this Section.

CHAPTER 21 HULL MONITORING SYSTEMS

Section 1 GENERAL PROVISIONS

21.1.1 General requirements

21.1.1.1 This Chapter applies to hull monitoring systems installed voluntarily on board ships.

21.1.1.2 The ships provided with hull monitoring systems in accordance with this Chapter may apply for a corresponding class notation.

21.1.1.3 The hull monitoring system may be used to collect and monitor hull stress, wave and operational parameters. The system is to give warning when changes of these data approach levels that require action.

21.1.1.4 For ships not complying with the requirements of this Chapter, other arrangements achieving safety level to the same extent as that specified by this Chapter may be used, subject to agreement of ISC.

21.1.1.5 In no case is the hull monitoring system (including sensors) to be installed to damage the hull structure and impair the performance of ship, or give rise to any potential safety hazard. The system is not intended as a substitute for correct judgment and responsibility of crew members.

21.1.2 Class notations

21.1.2.1 Upon request of the owner and in accordance with different sensors/components of the hull monitoring system, the following class notations may be assigned:

(1) HMS(×): Sensors monitoring the global longitudinal stress amidships are installed in the hull monitoring system, and also sensors/components monitoring other parameters may be selected, where within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by comma ","[①] and arranged in alphabetical order indicated in the table.

The following sensors/components in Table 21.1.2.1 may be selected for the hull monitoring system:

Letters Specifying Selected Sensors/Components Table 21.1.2.1

Letter	Description
Gn	Sensor monitoring the global hull strain
Dn	Sensor monitoring the local hull strain
On	Sensor monitoring the propulsion shaft(s) output
An	Sensor monitoring the axial acceleration
Mn	Device for monitoring of hull rigid body motions (six degrees of freedom)
Pn	Sensor monitoring the transient sea pressure acting on the hull (slamming)
Sn	Sensor monitoring the liquid motion pressures in tanks (sloshing)
Tn	Sensor monitoring the temperature
Bn	Device for monitoring the wave
Wn	Wind sensor
Nn	Navigation sensors
Ln	Backed up statistics and triggered time series to be sent to ISC periodically
Cn	Online link to loading instrument that is continuously up-dating the loading condition

Note: n denotes the number of sensors or devices.

(2) HMS-HSC (×): applicable to high speed craft and the sensors/components installed in the hull monitoring system are to comply with Table 21.4.3.2.

21.1.2.2 The class notations specified in 21.1.2.1 are to be assigned on the basis of approved drawings, certification of equipment and onboard survey.

21.1.2.3 The hull monitoring system (including sensors) is to be furnished with a type approval certificate of ISC or other equivalent documents acceptable to ISC.

21.1.3 Plans and documents

21.1.3.1 Documents containing the following information are to be submitted for approval:

---

① For example, a bulk carrier equipped with sensors monitoring the global longitudinal stress amidships and also sensors monitoring the axial acceleration and local hull strain may be assigned the class notation HMS (Gn, Dn, An) upon request of the owner.

(1) arrangement of sensors (including the information on each sensor);
(2) diagrams of power systems of the hull monitoring system.
21.1.3.2 The following documents are to be submitted for information:
(1) explanation on relevant software (including data processing unit);
(2) instruction manuals of the hull monitoring system.

21.1.4 Documents to be kept on board

21.1.4.1 Instruction manuals are to be kept on board. The manuals are at least to contain the following instructions on:
(1) operation;
(2) setting and calibration of sensors and system;
(3) identification of faults;
(4) repairs;
(5) systematic maintenance and function testing (showing how components and systems are to be tested and what is to be observed during the tests);
(6) interpretation of measuring results.
21.1.4.2 A log for maintenance and calibration of the hull monitoring system is to be kept on board.

Section 2 SYSTEM DESIGN

21.2.1 System composition and components

21.2.1.1 The hull monitoring system generally consists of a computer system (upper layer) and sensors installed in appropriate spaces (lower layer). Relevant information monitored by each sensor is transferred to the computer system. Upon receipt of such information, processing, display, alarm and storage are carried out by the computer system.
21.2.1.2 Sensors are to be so selected as to ensure that they are suitable for use in the marine environment and their type and accuracy are also suitable for use of the signal.
21.2.1.3 In the case that the ship already has installed a sensor for monitoring of a certain parameter, installation of a separate sensor for the hull monitoring system is not required.
21.2.1.4 Wave sensors may be used to monitor the wave condition, which produces a two dimensional spectrum (wave frequency and relative direction between wave and ship heading). Based on the spectrum, significant wave height, main wave direction and main wave period may be derived.
21.2.1.5 An anemometer giving speed and dominant direction of the wind may be used.
21.2.1.6 The speed of the ship may be taken from the GPS system or the speed log.
21.2.1.7 The course of the ship may be taken from the GPS system or the gyro compass.

21.2.2 System requirements

21.2.2.1 The hull monitoring system is to have functions of processing and display, and provide relevant information to ship's operators.
21.2.2.2 The system is to include a computer with sufficient capacity to perform the tasks required, e.g. process the sensor signals, display the information required on a screen, give alarms and store the data.
21.2.2.3 All electrical components that are exclusively used in the hull monitoring system, i.e. not sensors included in the navigation system, are to be powered through an UPS (un-interruptible power supply). In case of main power failure, the UPS is to have sufficient capacity to maintain normal operation of the hull monitoring system for at least 10 minutes.
21.2.2.4 The hull monitoring system is to automatically re-start for normal operation at return of main power.
21.2.2.5 In the case that the ship is equipped with a loading instrument, the still water shear forces and bending moments are to be transferred to the hull monitoring system. These data can be entered manually, read from a disk or transferred through an electronic link. The system may use this information to calculate the bending stress at the global strain positions.
21.2.2.6 The system is to be designed to give visual and audible alarm for at least the following incidents:
(1) power failure;
(2) sensor failure;
(3) signal from a sensor exceeding the alarm threshold value.
21.2.2.7 The programs and data held in the data recording system are to be protected from corruption by loss of power.
21.2.2.8 The user interface (display, keyboard and alarms) is at least to be installed on the bridge.

21.2.2.9 A data storage device suitable for saving time series and statistical information is to be used.
21.2.2.10 The system is to have minimum data storage capacity and functionality as specified in 21.3.9.
21.2.2.11 The hull monitoring system is to be configurable. The configuration is to include all settings that are relevant for a specific installation. Such settings will typically be calibration factors, sensors threshold values, filter cut-off frequencies, statistical calculations that are selected for the different sensors, etc.
21.2.2.12 The system is to have output port for providing Voyage Data Recorder with all IMO mandatory information (IMO resolution MSC.333(90) as amended by IMO resolution MSC.494 (104)) from the system. The port is to be compliant with IEC 61162.
21.2.2.13 Information on how to interpolate the vertical hull girder bending moment values from the loading instrument to the strain gauge positions is to be included in the computer programme of the system so that the loading instrument readings can be used for setting and checking the system.
21.2.2.14 Each strain gauge is initially to be set to a stress calculated in an agreed loading condition. This calculated stress is to be compatible with the output of the loading instrument and calculations made using the loading manual. The set-up is not to be carried out when dynamic stresses are present and is to be made when temperature effects are minimized and in absence of large gradients. The initial reading of the global strain gauge is to be checked against an agreed loading condition in calm water. In the event that the difference is greater than 5% of the approved value or 5 N/mm^2 occurs, whichever is the greater, the setup and subsequent checking are to be repeated.

21.2.3 System installation

21.2.3.1 The position of the strain gauges is to take account of the structural configuration of the ship and its mode of operation.
21.2.3.2 Deck-mounted strain gauges are to be protected from green seas on deck by appropriate siting or by using breakwaters or similar means. Strain gauges installed in other positions are to be suitably protected against external damages.
21.2.3.3 Motion sensors to measure motions are to be placed in positions where their functioning will not be affected by vibrations. Accelerometers and motion monitoring devices are to be mounted on a structural point where local structural vibration will be minimal. If resilient mounts are used, it is to be demonstrated that they have frequency characteristics that do not affect the signal in the frequency range of interest.
21.2.3.4 The rigid body motions are to be referred to the center of gravity in loaded condition.

21.2.4 Loads due to transient sea pressure (slamming)

21.2.4.1 Loads due to transient sea pressure (slamming) are preferably to be measured in terms of normal stress (strain) at the structure on which the pressure is acting, e.g. the pressure loads are to be measured as normal stress on longitudinal(s) or plating.
21.2.4.2 The loads may alternatively be measured using pressure transducer(s) mounted through the hull.
21.2.4.3 An accelerometer in the bow area may be used as an indicator of slamming incidents.

21.2.5 Loads due to liquid motions in tanks (sloshing)

21.2.5.1 Loads due to liquid motions in tanks (sloshing) are preferably to be measured in terms of stress (strain) in the structure on which the loads are acting.
21.2.5.2 The loads may alternatively be measured in terms of pressure using a pressure transducers mounted through the tank wall.

21.2.6 Structural temperature

21.2.6.1 Temperature sensors installed on the supporting structure① of cargo tanks containing cooled or heated cargo, are at least to have an operational range that covers the temperature of the cargo and the temperature in the structure when the cargo hold is empty.

Section 3 DATA PROCESSING AND STORAGE

21.3.1 General requirements

21.3.1.1 The parameters given in 21.4.3 are to be processed and made available for the hull monitoring

① For liquid tanks provided with the independent tank, the supporting structure means the saddle supporting the liquid tank; for the integral tank, the supporting structure mainly means the inner side of bulkhead.

display.
21.3.1.2 The measured signals are to be split into given time intervals for data processing. The results from the data processing for each time interval are to be stored. The time interval selected is to be set during the initial configuration of the software.
21.3.1.3 The type of processing each individual sensor's signal is to be defined during the initial configuration of the system. The configured information document can be accessed and consulted.

21.3.2 Data filtering

21.3.2.1 The software is to include high-pass and low-pass time domain digital filters. The cut-off frequency of the filters is to be configurable through the software.
21.3.2.2 The filters are to be designed to have a stop-band attenuation of at least 40 dB.
21.3.2.3 The filters are to be initiated at the start-up of the hull monitoring software, and be continuously active as long as the software is running during normal operation. The part of the filtered signal that is corrupted by the settling of the filter during start-up is not to be used in the subsequent data analyses.
21.3.2.4 The system is to have the capability to simultaneously perform filtering on all the measured time series of hull responses. The time series subjected to filtering are to be configurable through the software.
21.3.2.5 The system is to be able to put the time signal from all sensors measuring the ship responses through the following filtering processes, giving four different time series:
(1) no filtering (static value and both wave and vibrations responses are maintained);
(2) high-pass filtering (static value and low cycle temperature fluctuation are removed, the wave response and vibration responses of the signal are maintained);
(3) low-pass filtering (static value and the wave response is maintained);
(4) high-pass filtering (only the vibration response is maintained).
21.3.2.6 The software is to be able to display each of the four different time series described in 21.3.2.5.
21.3.2.7 The software is to be able to perform the data analyses described in 21.3.3 through 21.3.6 on each of the four different time series described in 21.3.2.5.

21.3.3 Statistical calculations

21.3.3.1 The software is to be able to perform the statistical calculations on the time series described in 21.3.1.2 and 21.3.2.5. The sensors selected for statistical calculations and statistical operation to be performed are to be configurable in the initial set-up of the software.
21.3.3.2 The following statistical parameters are to be calculated for each of the selected ship response parameters:
(1) maximum value;
(2) minimum value;
(3) mean value;
(4) standard deviation;
(5) skewness;
(6) kurtosis;
(7) mean zero crossing period.
21.3.3.3 For each of the ship responses, a histogram of all the peaks in the time history is to be established. The amplitude for each response is to be divided into pre-set intervals, and the number of peaks within each interval is to be counted. Hence, the histogram will contain the number of peak occurrences within each interval. The intervals are to be set during configuration of the software.
21.3.3.4 Similar histograms of the ship responses as described for the peaks in 21.3.3.3 are also to be established for the troughs.
21.3.3.5 For transient phenomena, such as liquid impacts (slamming and sloshing), the integrated energy of each impact is to be calculated.
21.3.3.6 For transient phenomena, such as liquid impacts (slamming and sloshing), the rise time of each impact is to be calculated. The limits for the calculation are to be configurable.
21.3.3.7 Based on assumptions of statistical distribution of the parameters derived in 21.3.3.2 to 21.3.3.5, a curve for the probability of exceeding a certain value within a given time period is to be estimated. The time period is to be configurable through the software.
21.3.3.8 Based on the probability curve, the probability of exceeding a predefined threshold value is to be found. The threshold value is to be configurable through the software.

21.3.4 Fatigue life estimation

21.3.4.1 The fatigue life of the structural elements equipped with strain sensors is to be estimated based on the measured time history.

21.3.4.2 The stress response histograms are to be established for each strain sensor using a type of cycle count method.

21.3.5 Loads due to transient sea pressure (slamming)

21.3.5.1 The number of transient peaks recorded by the sensor installed for the recording of slamming incidents exceeding the threshold level, is to be counted. The number count for a pre-defined time period is to be made available for the display. The threshold value and the time period are to be configurable through the software.

21.3.6 Hull stress

21.3.6.1 The hull girder strain (stress) may often be influenced by strain induced by temperature differences in the hull structure. This strain may be caused by temperature differences between the cargo and the environments or by partial heating of the hull structure due to sunshine. These effects may be reflected as low cycle variations of the measured strain. The strain due to these temperature differences is normally not to be included in the analyses performed by the hull monitoring system. The hull monitoring system is to have the capability to optionally remove the strain due to temperature differences in the hull girder.

21.3.6.2 The hull monitoring system is to have the capability to read the still water bending/torsion moments calculated by the loading instrument (if applicable). This information could either be typed manually into the hull monitoring system or be transferred electronically by disk or data link. Based on this information, the hull monitoring system is to be capable of computing the strain (stress) due to the still water bending moments at each position where a sensor measuring global hull strain (stress) is positioned. In the case when the sensor position does not correspond to a section for where the still water bending moments are computed, a linear interpolation between the moments on each side of the sensor position may be applied.

21.3.6.3 The hull monitoring system is to have the following three options for each individual strain sensor, to be selected independently, for input to the statistical analyses and the alarm handler. The option is to be selected during the initial installation of the hull monitoring system, with explanations given in the configuration file.

(1) measured strain as recorded (including possible effects due to temperature differences in the hull structure);

(2) measured strain high-passed filtered in order to remove low cycle temperature effects;

(3) measured strain high-passed filtered in order to remove low cycle temperature effects, and then have a strain offset added to the filtered strain signal, corresponding to the strain due to still water loading at each sensor position.

21.3.7 Threshold values and alarms

21.3.7.1 The hull monitoring software is to be designed to allow input of a minimum and a maximum threshold value for each sensor.

21.3.7.2 The measured values are to be compared to the given threshold values for each sensor. In the case that the computed value exceeds 80% of a threshold value, an alarm is to be given.

21.3.7.3 The cause of the alarm is to be automatically written to an alarm log that is to be stored on an electronic device.

21.3.8 Trend predictions

21.3.8.1 The results from the calculations for each time interval are to be arranged in such way that a sequence of the latest data from each individual sensor can be displayed as a trend.

21.3.8.2 A 4-hour data sequence from each individual sensors is to form the basis for a forecast trend prediction of the expected response from each individual sensor for at least the next hour. The measured and the predicted data is to be made available for the display.

21.3.8.3 When the signal from an individual sensor exceeds 80% of the specified threshold value for that sensor, the expected time to reach the threshold value is to be predicted based on trend analyses. The measured and the predicted data is to be made available for the display.

21.3.9 Data storage

21.3.9.1 The system is to have capacity to store at least one year of statistical data and 24 h of time series from all sensors. For sensors dedicated to slamming and sloshing measurements, it is sufficient to store the time sequences where the transients are exceeding a given threshold value.

21.3.9.2 The system is to have the capability to back-up the recorded data on a medium suitable to be

read on a personal computer (PC).

21.3.9.3 The data back-up files are to include all the recorded data presented on a suitable text format. The files are to include sufficient information to clearly describe the content of the files.

21.3.9.4 For each time interval, the system is to store the results from all the calculations for all the individual parameters recorded. The data is to be labelled with a time stamp (date and time) corresponding to the beginning of the time interval.

21.3.9.5 The system is to automatically store time series for all the measured parameters for a number of time intervals corresponding to at least a period of the last 4 h of recording. Time series older than this period is to automatically be deleted from the storage device.

21.3.9.6 The system is to have the functionality to permanently store the data specified in 21.3.9.5. The system is to have the storage capacity to permanently store at least 12 such periods.

Section 4 DISPLAY AND MONITORING

21.4.1 Display

21.4.1.1 The hull monitoring system is to have a display suitable for presentation of screen images.

21.4.1.2 The system is to have at least screens that display the following information:

(1) clearly visualize the position of each individual sensor;

(2) the status of each individual sensor, i.e. whether the sensor is operational or faulty;

(3) real time information of the measured time series of each individual sensor;

(4) signal level from each individual sensor compared to the threshold values;

(5) trends of the statistical parameters for each individual sensor, including forecast predictions;

(6) alarm status.

21.4.2 Manual input

21.4.2.1 The system is to be provided with means for manual input.

21.4.3 Extent of monitoring

21.4.3.1 For the class notation HMS(×), in addition to sensors monitoring the global longitudinal stress amidships which are installed port and starboard, other parameters may also be monitored. Recommended parameters to be monitored for the various types of ships and available sensors/components are given in Table 21.4.3.1.

Recommended Parameters to be Monitored for Types of Ships and Available Sensors/Components Table 21.4.3.1

No.	Parameter	Applicable ship type	Available sensors/ components	Remark
1	Vertical accelerations at forward perpendicular ($0.01L^{①}$) at centerline	a, b, c, d	A	① L is length of ship as defined in 1.1.2.1, Chapter 1, PART TWO of the Rules
2	Transverse acceleration in the 0.4L mid ship area	b, c, d	A	To monitor inertia loading on sensitive cargo. Sudden change in response may indicate irregular situations such as ingress of water in holds or at vehicle decks
3	Global longitudinal stress at the quarter length L/4 from mid ship (port and starboard)	$a^{②}$, $b^{②}$, $c^{②}$, $d^{③}$	G	② For ships with length L>180 m ③ For ships with hull girder sectional modulus < 1.5W_{rule} and with length L>180 m
4	Longitudinal stress close to bottom (L/2) amidships (port and starboard)	$b^{④}$, $c^{⑤}$	G	④ Longitudinal stresses (L/2) amidships below the neutral axis, e.g. at bilge area. Only for ships with large openings in deck ⑤ Longitudinal stresses (L/2) amidships below the neutral axis, e.g. at bilge area
5	Double bottom bending	$b^{⑥}$	D	⑥ For Bulk Carriers with class notation BC-B and BC-A, one strain sensor in inner bottom of each hold
6	Bending/shear stress in pillar bulkheads	$c^{⑦}$	D	⑦ For ships with operational limits with respect to draught with empty holds
7	Lateral loads at bottom near forward perpendicular	a, b, c, d	P	
8	Lateral loads at side	a, b, c, d	P	

No.	Parameter	Applicable ship type	Available sensors/ components	Remark
9	Lateral loads at the bow door	d⑧	P	⑧ For Ro-Ro Ships only
10	Loading instrument	a, b, c, d	C	Ship provided with a loading instrument may choose whether to establish an online link to the hull monitoring system
11	Position, speed/course	a, b, c, d	N	
12	Power output and revolutions of propulsor (s)	a, b, c, d	O	
13	Wave condition	a, b, c, d	B	
14	Wind condition	a, b, c, d	W	
15	Structural temperature	a	T	
16	Sloshing response of liquid in tanks	a	S	
17	Ship's attitude	a, b, c, d	M	
In the Table, a: oil tankers, petroleum asphalt tankers, chemical tanker, liquefied gas carriers; b: bulk carriers and ore carriers; c: container ships; d: general cargo ships, ro-ro ships, passenger ships and other ships.				

21.4.3.2 For the class notation HMS-HSC (×), the parameters to be monitored and corresponding types of sensors are given in Table 21.4.3.2.

Parameters to be Monitored for High Speed Craft and Corresponding Types of Sensors

Table 21.4.3.2

No.	Parameter	Available sensors	Remark
1	Vertical, transverse and longitudinal acceleration at the centerline of each hull in the fore body (fore of forward perpendicular)	A	Must be installed
2	Vertical, transverse and longitudinal acceleration at the longitudinal center of gravity (LCG)	A	Must be installed
3	Vertical, transverse and longitudinal acceleration at the centerline of each hull aft body (aft of aft perpendicular)	A	Must be installed
4	Global longitudinal stress amidships	G	Recommended to be installed
5	Global transverse stress in wet deck in center between each hull	D	Recommended to be installed (for multi-hull ships with length L>50 m)
6	Lateral loads at bottom near forward perpendicular	P	Recommended to be installed

Section 5 COMPONENT REQUIREMENTS

21.5.1 General requirements

21.5.1.1 All components are to be replaceable and designed for easy maintenance.

21.5.1.2 Electrical equipment and installation in hazardous areas are to be in accordance with PART FOUR of the Rules.

21.5.1.3 All equipment located at the navigation bridge is to be fitted with dimmers and has displays which do not interfere undue with the night vision of the officer of the watch.

21.5.2 Sensors

21.5.2.1 Strain sensors are to be designed in such way that the measured value is not influenced by changes in temperature.

21.5.2.2 Sensors for measuring global hull strain are to be mounted in such way that influence of local strain is minimized.

21.5.2.3 Sensors that are part of other systems, can be utilized in the hull monitoring system. Connections to such sensors are to be made in such way that they do not influence performance of the other systems. Failure of the hull monitoring system is not to influence the performance of other systems.

21.5.2.4 Accelerations are to be measured over a range of -20 m/s^2 to +20 m/s^2. The measurement uncertainty of the acceleration is to be less than 2% of the measured value, or 0.10 m/s^2, whichever is the greater.

21.5.2.5 The rigid body ship motions is to be measured by a device with integrated sensors, giving the 6º of freedom (3 translations and 3 rotations). The translations (accelerations) are to be measured over a range of -20 m/s^2 to +20 m/s^2. The angles are to be measured over a range of -90º to +90º, -45º to +45º and -180º to +180º, for the roll, pitch and yaw motions respectively. The measurement uncertainty is to be less than 2% of the measured value, or 0.10 m/s^2 for translations and 0.5º for angles, whichever is the greater.
21.5.2.6 The sea pressure acting on the hull is to be measured over a range of 0 – 2 MPa. The measurement uncertainty of the pressure is to be less than 2% of the measured value, or 0.01 MPa, whichever is the greater.
21.5.2.7 The liquid motion pressures in tanks (sloshing) is to be measured over a range of 0 – 4 MPa. The measurement uncertainty of the pressure is to be less than 4% of the measured value, or 0.02 MPa, whichever is the greater.
21.5.2.8 The structural strain is to be measured in a range related to the yielding strain of the material. The measurement uncertainty is to be less than 3% of the measured value or 20 micro strain, whichever is the greater. For ships made of steel or aluminium, a range from -2 000 micro strain to +2 000 micro strain can be assumed. For ships constructed using special material qualities or different types of materials, i.e. composite materials, the strain range is to be specially considered by ISC.
21.5.2.9 The sensors installations designed for low frequency responses, i. e. motions and wave loading are to record the physical quantities within the specified uncertainties within the frequency range 0.01 – 3 Hz. Installations designed to measure slamming responses are to record the physical quantity within the specified uncertainties in the frequency range 5 – 100 Hz. Installations designed to measure sloshing responses are to record the physical quantity within the specified uncertainties in the frequency range 30 – 1200 Hz. For the physical quantity recorded above, the uncertainty is to be within the specified range.
21.5.2.10 The data processing unit is to be capable of handling information supplied by all sensors including navigational instruments at the actual transfer rate.
21.5.2.11 The information from the sea-state parameters is at least to be updated and submitted every 10 minutes.

21.5.3 Signal conditioning units

21.5.3.1 The signal conditioning units are to be matched to the connected sensor.
21.5.3.2 The signals from analogue sensors are to be low-pass filtered prior to digitising to avoid signal noise. The filters are to be matched to the frequency range for the different sensors.
21.5.3.3 The sensors installations designed for low frequency responses, i.e. motions and wave loading are to be digitised with at least 20 Hz. Installations designed to measure slamming responses are to be digitised with at least 500 Hz. Installations designed to measure sloshing responses in tanks are to be digitised with at least 3 kHz.

CHAPTER 22 ADDITIONAL REQUIREMENTS FOR ERGONOMIC CONTAINER LASHING

Section 1 GENERAL PROVISIONS

22.1.1 Application

22.1.1.1 The provisions of this Chapter are voluntary and the aim of this Chapter is to ensure that persons engaged in carrying out container securing operations on deck have safe working conditions. This Chapter applies to container ships and ships which are specifically designed and fitted for the purpose of carrying containers on deck.

22.1.2 Class notation

22.1.2.1 The following class notation may be assigned to those complying with the requirements specified in this Chapter:
(1) Ergonomic Container Lashing: ECL

22.1.3 Definitions

22.1.3.1 Fencing is a generic term for guardrails, safety rails, safety barriers and similar structures that provide protection against the falls of persons.
22.1.3.2 Lashing positions include positions:
(1) in between container stows on hatch covers;
(2) at the end of hatches;
(3) on outboard lashing stanchions/pedestals;
(4) outboard lashing positions on hatch covers; and
(5) any other position where people work with container securing.
22.1.3.3 Stringers are the uprights or sides of a ladder.
22.1.3.4 Turnbuckles and lashing rods specified in this Chapter include similar cargo securing devices.

22.1.4 Plans and information

22.1.4.1 The following information is to be submitted:
(1) Details of container stowage arrangements;
(2) Details of working areas including means of access, fall protection arrangements and anti-slip surfaces;
(3) Details of lashing bridges including stowage arrangements for lashing bars, means of access and fall protection arrangements;
(4) Details of walkways and transit areas including fall protection and anti-slip surfaces;
(5) Details of access openings, ramps, ladders, steps, hatchways and coamings;
(6) Details of container securing fittings including fixed and loose fittings;
(7) Details of deck lighting;
(8) Details of reefer power outlets.

Section 2 SAFE ACCESS DESIGN

22.2.1 General provisions

22.2.1.1 The minimum clearance for transit areas is to be at least 2 m high and 600 mm wide. See dimensions "*B*" in Figure 22.2.1, "*J*" in Figure 22.2.4, "K_1" in Figure 22.2.2 and Table 22.2.1.
22.2.1.2 All relevant deck surfaces used for movement about the ship and all passageways and stairs are to have non-slip surfaces.
22.2.1.3 Where necessary for safety, walkways on deck are to be delineated by painted lines or otherwise marked by pictorial signs.
22.2.1.4 All protrusions in access ways, such as cleats, ribs and brackets that may give rise to a trip hazard are to be highlighted in a contrasting colour.

22.2.2 Lashing position design (platforms, bridges and other lashing positions)

22.2.2.1 Lashing positions are to be designed to eliminate the use of three high lashing bars and be positioned in close proximity to lashing equipment stowage areas. Lashing positions are to be designed to provide a clear work area which is unencumbered by deck piping and other obstructions and take into consideration:

(1) the need for containers to be stowed within safe reach of the personnel using the lashing position so that the horizontal operating distance from the securing point to the container does not exceed 1,100 mm and not less than 220 mm for lashing bridges and 130 mm for other positions, see dimensions "C_1" and "C_2" in Figure 22.2.2, "C_3" in Figure 22.2.1 and Table 22.2.1;

(2) the size of the working area and the movement of lashing personnel; and

(3) the length and weight of lashing gear and securing components used.

22.2.2.2 The width of the lashing positions is preferably to be 1,000 mm, but not less than 750 mm. See dimensions "*A*" in Figure 22.2.1, "*GL*" and "*GT*" in Figure 22.2.3, "*I*" in Figure 22.2.4, "*K*" in Figure 22.2.2 and Table 22.2.1.

22.2.2.3 The width of permanent lashing bridges is to be:

(1) 750 mm between top rails of fencing, see dimension "*F*" in Figure 22.2.2 and Table 22.2.1; and

(2) a clear minimum of 600 mm between storage racks, lashing cleats and any other obstruction, see dimension "F_1" in Figure 22.2.2 and Table 22.2.1.

22.2.2.4 Platforms on the end of hatches and outboard lashing stations are preferably to be at the same level as the top of the hatch covers.

22.2.2.5 Toe boards (or kick plates) are to be provided around the sides of elevated lashing bridges and platforms to prevent securing equipment from falling and injuring people. Toe boards are preferably to be 150 mm high, however, where this is not possible they are to be at least 100 mm high.

22.2.2.6 Any openings in the lashing positions through which people can fall are to be possible to be closed.

22.2.2.7 Lashing positions are not to contain obstructions, such as storage bins or guides to reposition hatch covers.

22.2.2.8 Lashing positions which contain removable sections are to be capable of being temporarily secured.

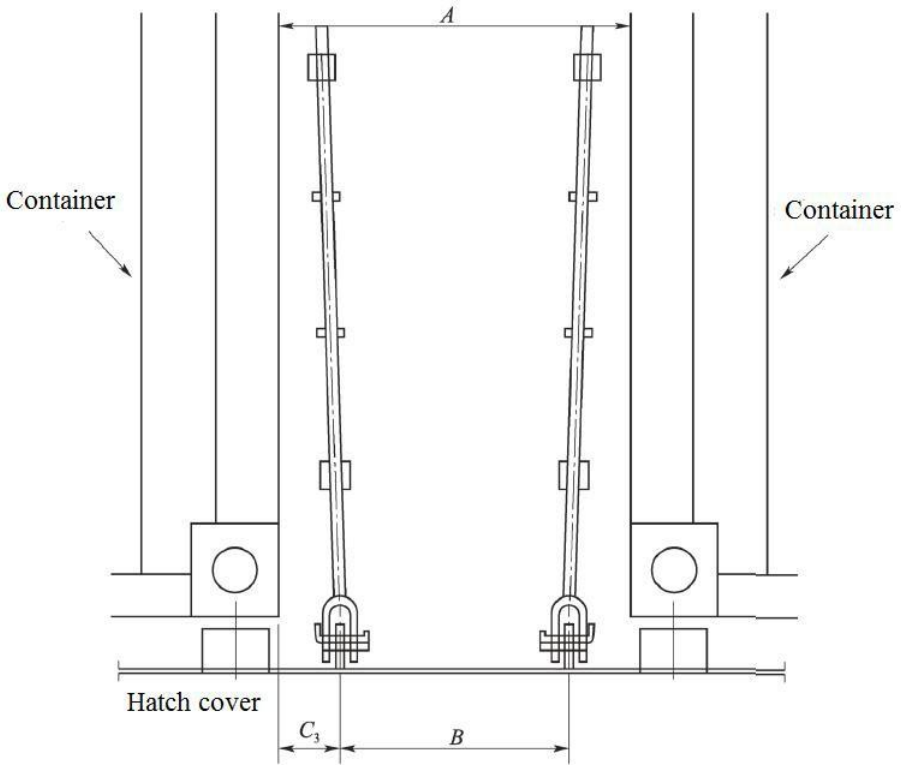


Figure 22.2.1

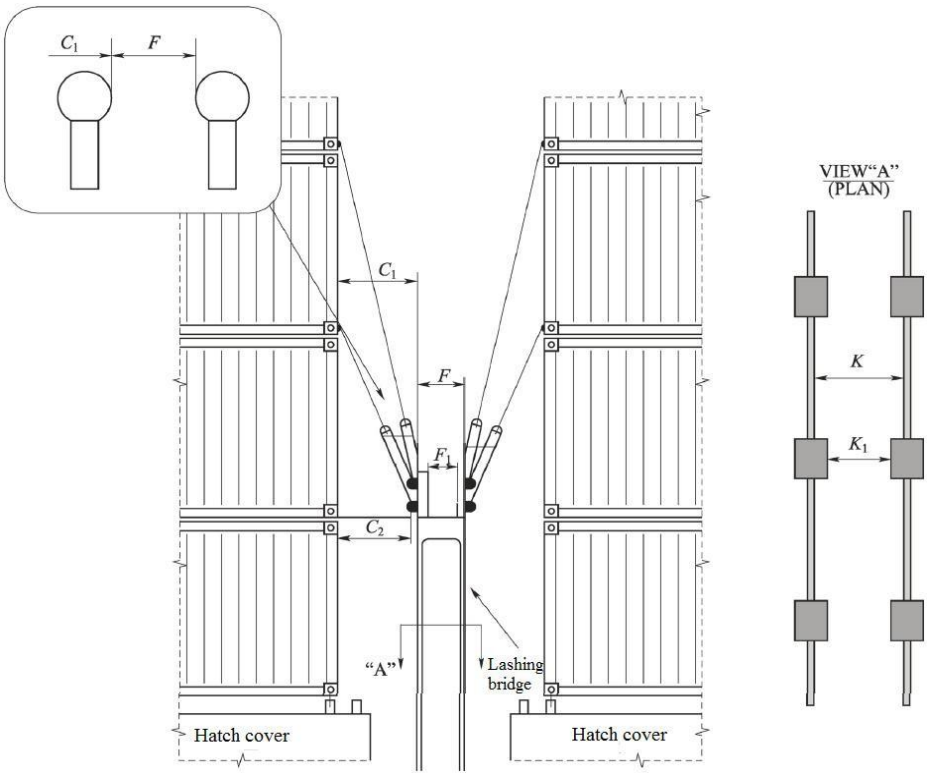


Figure 22.2.2

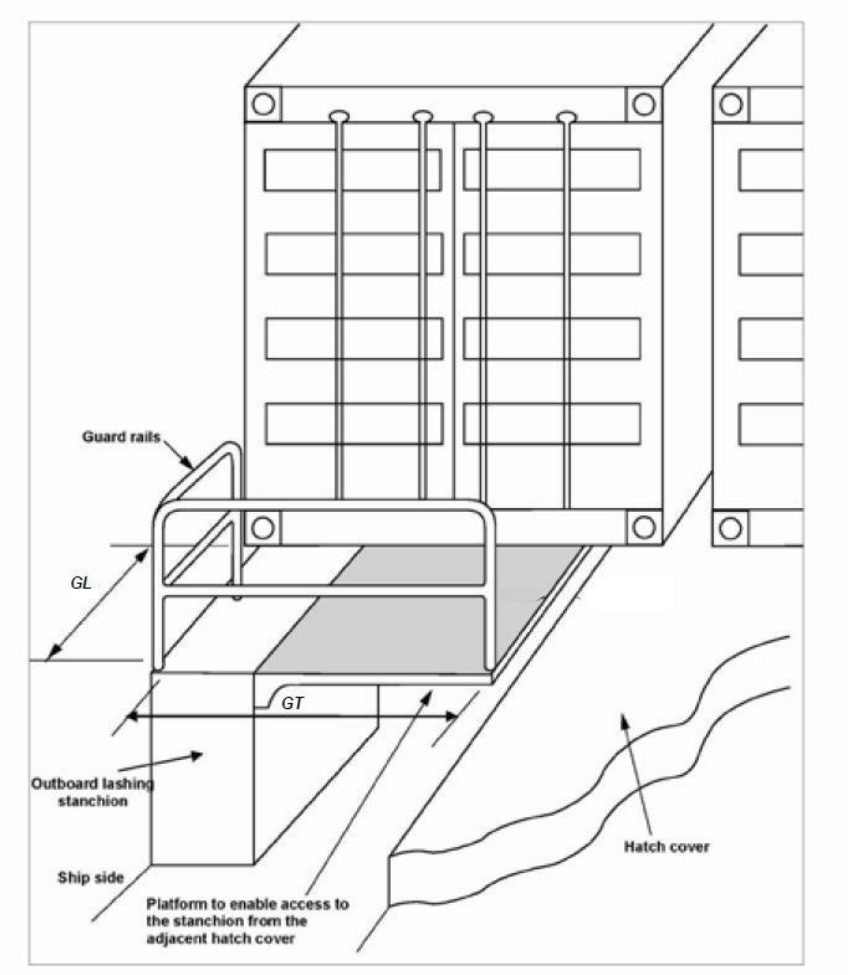


Figure 22.2.3

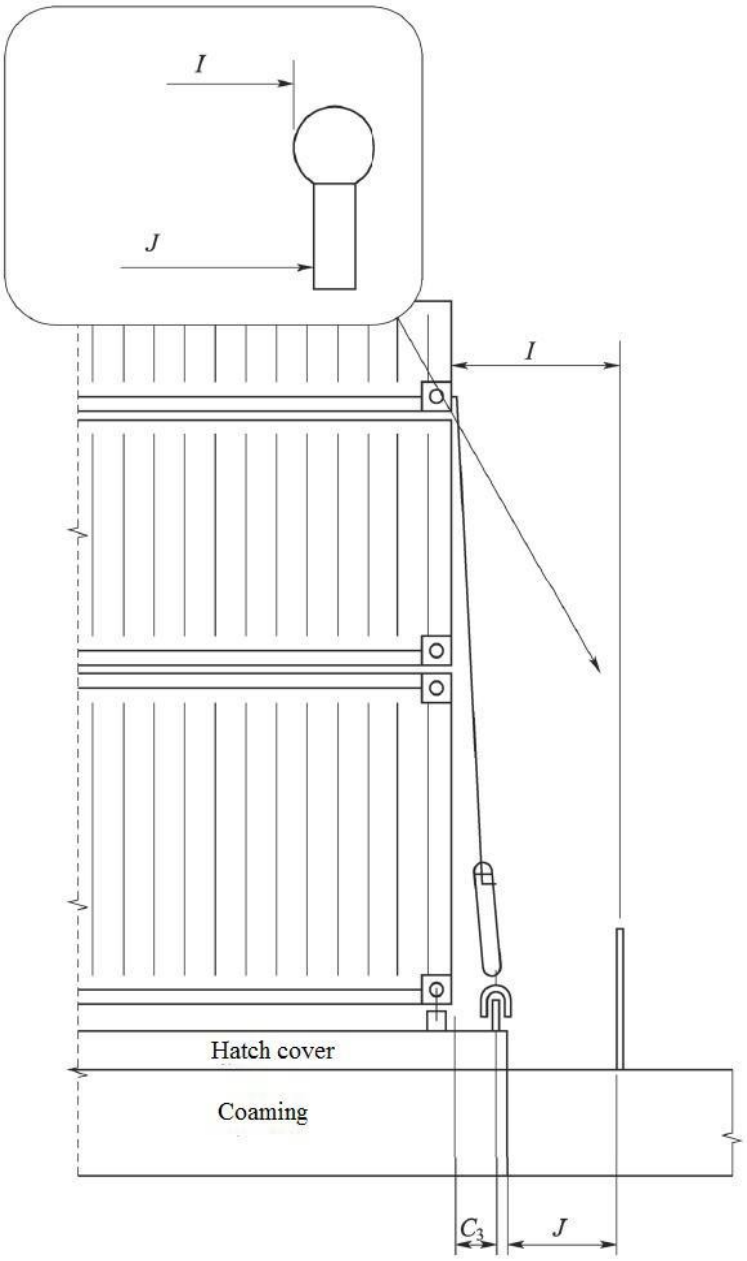


Figure 22.2.4

Container securing dimensions as shown in Figures 22.2.1 to 22.2.4 are listed in Table 22.2.1:

Table 22.2.1

Dimension	Description	Requirement (mm)
A	Width of work area between container stacks	750 minimum
B	Distance between lashing plates on deck or on hatch covers	600 minimum
C_1	Distance from lashing bridge fencing to container stack	1100 maximum
C_2	Distance from lashing plate to container stack (lashing bridge)	220 minimum
C_3	Distance from lashing plate to container stack (elsewhere)	130 minimum
F	Width of lashing bridge between top rails of fencing	750 minimum
F_1	Width of lashing bridge between storage racks, lashing cleats and any other obstruction	600 minimum
GL	Width of working platform for outboard lashing – fore/aft	750 minimum
GT	Width of working platform for outboard lashing – transverse	750 minimum
I	Width of work platform at end of hatch cover or adjacent to superstructure	750 minimum
J	Distance from edge of hatch cover to fencing	600 minimum
K	Width of lashing bridge between top rails of fencing	750 minimum
K_1	Width of lashing bridge between the pillars of the lashing bridge	600 minimum
Notes:		

B — Measured between the centres of the lashing plates. C_1 — Measured from inside of fencing. C_2, C_3 — Measured from centre of lashing plate to end of container. *F*, *K* — Measured to inside of fencing. *GL* — Measured from end of container to inside of fencing. *GT* — Measured to inside of fencing. *I* — Measured to inside of fencing. *J* — Measured to inside of fencing.

22.2.3 Fencing design

22.2.3.1 Bridges and platforms, where appropriate, are to be fenced. As a minimum, fencing design is to take into consideration:

(1) the strength and height of the rails are to be designed to prevent workers from falling;

(2) flexibility in positioning the fencing of gaps. A horizontal unfenced gap is not to be greater than 300 mm;

(3) provisions for locking and removal of fencing as operational situations change based on stowage anticipated for that area;

(4) damage to fencing and how to prevent failure due to that damage; and

(5) adequate strength of any temporary fittings. These are to be capable of being safely and securely installed.

22.2.3.2 The top rail of fencing is to be 1 m high from the base, with two intermediate rails. The opening below the lowest course of the guard rails is not to exceed 230 mm. The other courses are to be not more than 380 mm apart.

22.2.3.3 Where possible fences and handrails are to be highlighted with a contrasting colour to the background.

22.2.3.4 Athwartships cargo securing walkways are to be protected by adequate fencing if an unguarded edge exists when the hatch cover is removed.

22.2.4 Ladder and manhole design

22.2.4.1 Where a fixed ladder gives access to the outside of a lashing position, the stringers are to be connected at their extremities to the guardrails of the lashing position, irrespective of whether the ladder is sloping or vertical.

22.2.4.2 Where a fixed ladder gives access to a lashing position through an opening in the platform, the opening shall be protected with either a fixed grate with a lock back mechanism, which can be closed after access, or fencing. Grabrails are to be provided to ensure safe access through the opening.

22.2.4.3 Where a fixed ladder gives access to a lashing position from the outside of the platform, the stringers of the ladder are to be opened above the platform level to give a clear width of 700 to 750 mm to enable a person to pass through the stringers.

22.2.4.4 A fixed ladder is not to slope at an angle greater than 25° from the vertical. Where the slope of a ladder exceeds 15° from the vertical, the ladder is to be provided with suitable handrails not less than 540 mm apart, measured horizontally.

22.2.4.5 A fixed vertical ladder of a height exceeding 3 m, and any fixed vertical ladder, from which a person may fall into a hold, is to be fitted with guard hoops, which are to be constructed in accordance with paragraphs 22.2.4.6 and 22.2.4.7.

22.2.4.6 The ladder hoops are to be uniformly spaced at intervals not exceeding 900 mm and are to have a clearance of 750 mm from the rung to the back of the hoop and be connected by longitudinal strips secured to the inside of the hoops, each equally spaced round the circumference of the hoop.

22.2.4.7 The stringers are to be carried above the floor level of the platform by at least 1 m and the ends of the stringers are to be given lateral support and the top step or rung is to be level with the floor of the platform unless the steps or rungs are fitted to the ends of the stringers.

22.2.4.8 As far as practicable, access ladders and walkways, and work platforms are to be designed so that workers do not have to climb over piping or work in areas with permanent obstructions.

22.2.4.9 There are to be no unprotected openings in any part of the workplace. Access opening must be protected with handrails or access covers that can be locked back during access.

22.2.4.10 As far as practicable, manholes are not to be situated in transit areas, however, if they are, proper fencing is to protect them.

22.2.4.11 Access ladders and manholes are to be large enough for persons to safely enter and leave.

22.2.4.12 A foothold at least 150 mm deep is to be provided.

22.2.4.13 Handholds are to be provided at the top of the ladder to enable safe access to the platform to be gained.

22.2.4.14 Manhole openings that may present a fall hazard are to be highlighted in contrasting colour around the rim of the opening.
22.2.4.15 Manhole openings at different levels of the lashing bridge are not to be located directly below one another, as far as practicable.

Section 3 LASHING SYSTEMS

22.3.1 General provisions

Lashing systems, including tensioning devices, are to:
(1) conform to international standards (ISO 3874), where applicable;
(2) be compatible with the planned container stowages;
(3) be compatible with the physical ability of persons to safely hold, deploy and use such equipment;
(4) be uniform and compatible, e.g. twistlocks and lashing rod heads are not to interfere with each other;
(5) be subject to a periodic inspection and maintenance regime. Non-conforming items are to be segregated for repair or disposal; and
(6) be according to the CSM.

22.3.2 Twistlock design

22.3.2.1 Shipowners are to ensure that the number of different types of twistlocks provided for cargo securing is kept to a minimum and clear instructions are provided for their operation. The use of too many different types of twistlocks may lead to confusion as to whether the twistlocks are locked.
22.3.2.2 The design of twistlocks is to ensure the following:
(1) positive locking with easy up and down side identification;
(2) dislodging from corner fitting is not possible even when grazing a surface;
(3) access and visibility of the unlocking device is effective in operational situations;
(4) unlocked positions are easily identifiable and do not relock inadvertently due to jolting or vibration; and
(5) unlocking poles are as light as possible, of a simple design for ease of use.
22.3.2.3 Where it is not feasible to entirely eliminate working on the tops of container stows, the twistlock designs used are to minimize the need for such working, e.g. use of SATLs, fully automatic twistlocks or similar design.

22.3.3 Lashing rod design

22.3.3.1 The design of containership securing systems is to take into account the practical abilities of the workers to lift, reach, hold, control and connect the components called for in all situations anticipated in the cargo securing plan.
22.3.3.2 The maximum length of a lashing rod is to be sufficient to reach the bottom corner fitting of a container on top of two high cube containers and be used in accordance with the instructions provided by the manufacturers.
22.3.3.3 The weight of lashing rods is to be minimized as low as possible consistent with the necessary mechanical strength.
22.3.3.4 The head of the lashing rod that is inserted in the corner fitting is to be designed with a pivot/hinge or other appropriate device so that the rod does not come out of the corner fitting accidentally.
22.3.3.5 The rod's length in conjunction with the length and design of the turnbuckle is to be such that the need of extensions is eliminated when lashing high cube (9'6") containers.
22.3.3.6 Lightweight rods are to be provided where special tools are needed to lash high cube containers.

22.3.4 Turnbuckle design

22.3.4.1 Turnbuckle end fittings are to be designed to harmonize with the design of lashing rods.
22.3.4.2 Turnbuckles are to be designed to minimize the work in operating them.
22.3.4.3 Anchor points for turnbuckles are to be positioned to provide safe handling and to prevent the bending of rods.
22.3.4.4 To prevent hand injury during tightening or loosening motions, there is to be a minimum distance of 70 mm between turnbuckles.
22.3.4.5 The turnbuckle is to incorporate a locking mechanism which will ensure that the lashing does not work loose during the voyage.
22.3.4.6 The weight of turnbuckles is to be minimized as low as possible consistent with the necessary mechanical strength.

22.3.5 Storage bins and lashing equipment stowage design

22.3.5.1 Bins or stowage places for lashing materials are to be provided.

22.3.5.2 All lashing gear are to be stowed as close to its intended place of use as possible.

22.3.5.3 The stowage of securing devices is to be arranged so they can easily be retrieved from their stowage location.

22.3.5.4 Bins for faulty or damaged gear are also to be provided and appropriately marked.

22.3.5.5 Bins are to be of sufficient strength.

22.3.5.6 Bins and their carriers are to be designed to be lifted off the vessel and restowed.

Section 4 LIGHTING DESIGN

22.4.1 A lighting plan is to be developed to provide for:

22.4.1.1 the proper illumination of access ways, not less than 10 lux (1 foot candle), taking into account the shadows created by containers that may be stowed in the area to be lit, for example different length containers in or over the work area;

22.4.1.2 a separate fixed or temporary (where necessary) lighting system for each working space between the container bays, which is bright enough, not less than 50 lux (5 foot candle), for the work to be done, but minimizes glare to the deck workers;

22.4.1.3 such illumination is, where possible, to be designed as a permanent installation and adequately guarded against breakage; and

22.4.1.4 the illumination intensity is to take into consideration the distance to the uppermost reaches where cargo securing equipment is utilized.

Section 5 SPECIALIZED CONTAINER SAFETY DESIGN

22.5.1 Temperature controlled unit power outlets are to provide a safe, watertight electrical connection.

22.5.2 Temperature controlled unit power outlets are to feature a heavy duty, interlocked and circuit breaker protected electrical power outlet. This is to ensure the outlet can not be switched "live" until a plug is fully engaged and the actuator rod is pushed to the "ON" position. Pulling the actuator rod to the "OFF" position is to manually de-energize the circuit.

22.5.3 The temperature controlled unit power circuit is to de-energize automatically if the plug is accidentally withdrawn while in the "ON" position. Also, the interlock mechanism is to break the circuit while the pin and sleeve contacts are still engaged. This provides total operator safety and protection against shock hazard while eliminating arcing damage to the plug and receptacle.

22.5.4 Temperature controlled unit power outlets are to be designed to ensure that the worker is not standing directly in front of the socket when switching takes place.

22.5.5 The positioning of the temperature controlled unit feed outlets is not to be such that the flexible cabling needs to be laid out in such a way as to cause a tripping hazard.

22.5.6 Stevedores or ship's crew who are required to handle temperature controlled unit cables and/or connect and disconnect reefer units are to be given training in recognizing defective wires and plugs.

22.5.7 Means or provisions are to be provided to lay the temperature controlled unit cables in and protect them from lashing equipment falling on them during lashing operations.

22.5.8 Defective or inoperative temperature controlled unit plugs/electrical banks are to be identified and confirmed as "locked out/tagged out" by the vessel.

CHAPTER 23 ADDITIONAL REQUIREMENTS FOR SHIPS OPERATING IN LOW AIR TEMPERATURE ENVIRONMENTS

Section 1 GENERAL PROVISIONS

23.1.1 General requirements

23.1.1.1 This Chapter applies for ships intended to operate in low air temperature environments and in addition, for ships operating in areas and during periods where more severe ice and snow accretion are likely to occur.

23.1.1.2 Ships applying for ISC Anti-Cold Climate notation are to comply with the requirements of this Chapter in addition to the requirements of other Chapters of the Rules, as applicable.

23.1.1.3 Low air temperature environments may affect hull structure, function of equipment and systems, human performance and safety of the ships' operation. To remove or mitigate adverse impacts of low air temperatures and take anti-cold climate measures reasonably and effectively, the following risks, but not limited to, are to be taken into account:

(1) loss of material properties;
(2) reduced efficiency or failure of machinery/equipment;
(3) freezing of cargo;
(4) freezing of ballast water;
(5) reduced habitability;
(6) reduced human performance;
(7) frostbite;
(8) ice accretion of the ship above the waterline.

23.1.2 Definitions

23.1.2.1 For the purpose of this Chapter:

(1) Mean Daily Low Temperature (MDLT) means the mean value of the daily low temperature for each day of the year over a minimum 10 year period. A data set acceptable to the Administration may be used if 10 years of data is not available. (Refer to Figure 23.1.2.1 for MDLT)

(2) Low air temperature environment means water areas with the lowest MDLT (LMDLT) lower than -10℃, such as the Arctic Ocean, the Antarctic Ocean, Gulf of St. Laurence, the northern Baltic Sea, Sea of Okhotsk, the Bohai Sea and the northern Huanghai Sea, etc. In general, waters of this type are covered by regional sea ice in the winter. (Refer to Figure 23.1.2.1 for LMDLT)

(3) Design Service Temperature (DST) means a temperature indicator set for the ship measuring the service performance of materials, equipment and systems in low air temperature environments in the design. The temperature is determined by the shipowner in accordance with the purpose and service condition of the ship and is in general to be set at least 10 ℃ below the LMDLT for the intended area and season of operation.

(4) Minimum Anticipated Temperature (MAT) means the lowest ambient temperature that may be anticipated in the intended navigation areas of the ship during the voyage and is in general to be taken as at least 20℃ lower than LMDLT.

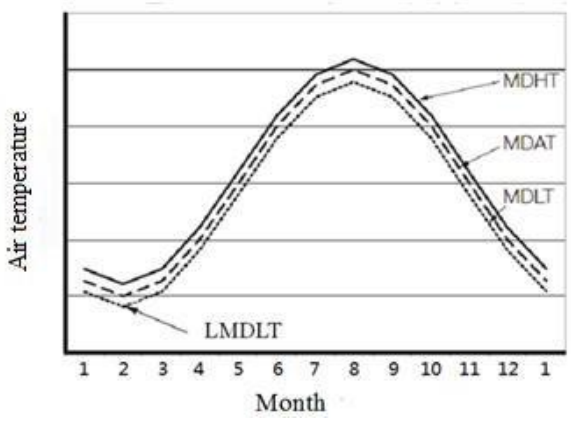
(5) Positive temperature spaces mean spaces that are maintained constantly above 0 ℃ by lagging heat insulating materials or installing air conditioning systems thus making freezing unlikely.

(6) Low temperature spaces mean spaces where the ambient temperature is constantly below 0 ℃ thus making freezing likely.

(7) Anti-icing means preventing the exposed areas and facility surfaces from accumulation and freezing of ice and snow (i.e. ice and snow accretion) by means of covering, heating or other measures which are generally applied to areas such as superstructures, deck passageways, railings and handholds, cargo decks and helicopter platforms as well as equipment for navigation, mooring, life-saving and fire-fighting.

(8) De-icing means removing ice and snow accretion in the exposed areas and facility surfaces by using tools.

(9) Anti-freezing means keeping the liquid inside tanks, equipment and pipelines exposed to low air temperature environments from freezing by excitation, circulation, insulation and heating, etc.



Notes:

MDHT – Mean Daily High Temperature
MDAT – Mean Daily Average Temperature
MDLT – Mean Daily Low Temperature
LMDLT – Lowest Mean Daily Low Temperature

Figure 23.1.2.1 General Temperature Definitions

23.1.3 Class notations

23.1.3.1 The following Anti-Cold Climate notations may be assigned upon application of the shipowner subject to compliance of the ship with the provisions of this Chapter:

(1) ACC (DST): Ships that are plan approved and surveyed by ISC and found compliant with the requirements of this Chapter may be assigned with the class notation, i.e. the basic Anti-Cold Climate notation.

(2) ACC-POLAR (DST): Ships that are plan approved and surveyed by ISC and found compliant with the requirements of this Chapter and that are anticipated to operate in polar waters may be assigned with the class notation, i.e. the polar Anti-Cold Climate notation.

(3) H (DST): Ships that are plan approved and surveyed by ISC and the materials used for hull structures of which comply with the relevant requirements in Sections 2 and 10 of this Chapter may be assigned with the class notation, i.e. the hull Anti-Cold Climate notation.

(4) DE-ICE: Ships that are plan approved and surveyed by ISC and found compliant with the requirements in Section 11 of this Chapter may be assigned with the class notation, i.e. the DE-ICE notation.

23.1.4 Plans and documents

23.1.4.1 For H (DST) notation, the relevant structural plans to be submitted for approval as required by other Chapters of the Rules are to contain steel grades of the materials.

23.1.4.2 In addition to 23.1.4.1 above, for ACC (DST), ACC-POLAR (DST) notations, anti-cold climate design plans and documents as follows are to be submitted for approval:

(1) General arrangement highlighting anti-cold climate features and design service temperatures;

(2) List of anti-cold climate equipment and systems;

(3) Details of main/auxiliary engines arrangements (including anti-cold climate features such as heating arrangement);

(4) Details of materials specification/heating arrangements for exposed pipes/components;

(5) Details of anchoring lifting appliance anti-cold arrangements;

(6) Details of materials specification/heating arrangements for exposed cabling/components;

(7) Details of anti-cold climate for fire-fighting appliances;

(8) Details of anti-cold climate for life-saving appliances;

(9) Details of heating arrangements for cabins;

(10) Details of cabin and escape route arrangements;

(11) Details of anti-freezing arrangements for tanks;

(12) Inventory and locations of de-icing measures;

(13) Calculations of ice accretion stability;

(14) Details of anti-freezing arrangements for emergency towing (applicable to tankers);

(15) Anti-freezing arrangements for crew's working passageways;

(16) Structural strength calculation of the cargo maintenance system (additional ice accretion load, applicable to liquefied gas carriers);

(17) Diagram of the environmental control system (dew-point temperature control, applicable to liquefied

gas carriers);
(18) Anti-cold climate arrangements for the rescue area (applicable to offshore supply vessels);
(19) Anti-cold climate arrangements for cargo securing equipment (applicable to container ships);
(20) Anti-cold climate arrangements for the helicopter deck or hovering area.
23.1.4.3 For ACC (DST), ACC-POLAR (DST) notations, the following plans and documents are to be submitted for information:
(1) anti-cold climate design instructions;
(2) anti-cold climate operational and maintenance procedures, for example:
① continuous circulation of fluids and/or heating media;
② use of heating arrangements in low air temperature environments;
③ application of lubricants in exposed and low temperature spaces;
④ applicable locations and application procedures of antifreeze;
⑤ use of oil fuel for emergency generators and lifeboat/rescue boat engines in low air temperature environments;
⑥ applicable antifreeze and cleaning solutions for bridge windows;
⑦ draining and/or drying of pipelines prone to freezing;
⑧ characteristics and application procedures of de-icing tools.
23.1.4.4 For DE-ICE notation, refer to 23.11.3 for the requirements for submittal of plans and documents.
23.1.4.5 Anti-cold climate design diagrams and anti-cold climate operational and maintenance procedures are always to be kept on board ships.

Section 2 MATERIALS AND WELDING

23.2.1 General requirements

23.2.1.1 For ships intended to operate in low air temperature environments, the materials used for hull structures and machinery and equipment are to satisfy the normal usage demands at the design service temperature.
23.2.1.2 Material grades are to be selected based on design service temperature, material class and thickness.
23.2.1.3 Materials and welding are to comply with the relevant requirements of PART TWO of the Rules in addition to the requirements of this Section.

23.2.2 Materials of hull structural members

23.2.2.1 Steels for hull structures exposed to low air temperature environments are not to be of lower grade than those specified in Table 23.2.2.2(1) and the material grade is to be selected in accordance with Tables 23.2.2.2(2), 23.2.2.2(3) and 23.2.2.2(4).
23.2.2.2 As a special product, the steels for anchor chain cables and offshore mooring chains are to be in accordance with the requirements of Section 12, Chapter 3, PART ONE of ISC Rules for Materials and Welding, except that the use of grade 1 chain cables is not permitted. The highest temperature for the impact test is -20℃.
23.2.2.3 The materials for hatch coamings, hatch covers, foundations of cranes and windlasses are at least to be of class II. The material grade is to be selected in compliance with the requirements for material class and thickness as given in Tables 23.2.2.2(2), 23.2.2.2(3) and 23.2.2.2(4) respectively.

Material Class in Low Air Temperature Environments **Table 23.2.2.2(1)**

Structural member category	Structural member	Material class	
		Within 0.4*L* amidships	Outside 0.4*L* amidships
Secondary	Deck plating exposed to weather in general, side plating above CWL⑤, transverse bulkheads above CWL⑥	I	I
Primary	Strength deck plating① Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above CWL⑥ Top wing tank bulkhead above CWL⑥	II	I

Structural member category	Structural member	Material class	
		Within 0.4*L* amidships	Outside 0.4*L* amidships
Special	Sheer strake at strength deck; stringer plate in strength deck②; deck strake at longitudinal bulkhead ③ ; continuous longitudinal hatch coamings④	III	II

Notes: ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

② Not to be less than grade E/EH within 0.4*L* amidships in ships with length exceeding 250 m.

③ In ships with breadth exceeding 70 m at least three deck strakes are to be class III.

④ Not to be less than grade D/DH.

⑤ The Cold Waterline (CWL) is to be taken as 300 mm below the minimum design Ballast Waterline (BWL).

⑥ Applicable to platings attached to shell plating exposed to low air temperature environments. At least one strake is to be considered as the exposed plating which is to be at least 600 mm in width.

Material Grade Requirements for Class I in Low Air Temperature Environments

Table 23.2.2.2(2)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B①	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	A	AH	A	AH	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	B	AH	B	AH	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	B	AH	B	AH	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	B	AH	D	DH	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	D	DH	D	DH	E	EH	E	EH	–	FH
$45 < t \leq 50$	D	DH	D	DH	E	EH	E	EH	–	FH	–	FH

Note: ① If fully killed, grade A steel is also acceptable.

Material Grade Requirements for Class II in Low Air Temperature Environments

Table 23.2.2.2(3)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	B	AH	B	AH	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	B	AH	D	DH	D	DH	E	EH	E	EH	–	FH
$30 < t \leq 40$	D	DH	D	DH	E	EH	E	EH	–	FH	–	FH
$40 < t \leq 45$	D	DH	D	DH	E	EH	–	FH	–	FH	–	–
$45 < t \leq 50$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–

Material Grade Requirements for Class III in Low Air Temperature Environments

Table 23.2.2.2(4)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	B	AH	B	AH	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	B	AH	D	DH	D	DH	E	EH	E	EH	–	FH
$20 < t \leq 25$	D	DH	D	DH	E	EH	E	EH	E	FH	–	FH
$25 < t \leq 30$	D	DH	E	EH	E	EH	E	EH	–	FH	–	FH
$30 < t \leq 35$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–
$35 < t \leq 40$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–
$40 < t \leq 50$	E	EH	E	EH	–	FH	–	FH	–	–	–	–

23.2.3 Machinery materials

23.2.3.1 Deck machinery materials are to comply with the requirements for steels for machinery structures in Section 6, Chapter 3, PART ONE of ISC Rules for Materials and Welding. The materials for lifting appliances are to be in accordance with ISC Rules for Lifting Appliances of Ships and Offshore Installations, and the materials not covered in that Rules are to comply with the requirements of 23.2.3.2 below.

23.2.3.2 The material classes of members/components of machinery installations exposed to low air temperature environments are to be in accordance with Table 23.2.3.2; the plates are to comply with the requirements of 23.2.2.1 and castings and forgings are to comply with the requirements of 23.2.3.6 and 23.2.3.7 respectively.

Material Classes for Equipment and Members/Components **Table 23.2.3.2**

Main component	Sub-component	Class
Deck machinery and equipment		
Windlass	Cable lifter, gear wheel, shaft	II
	Foundation bolt, brake system, stripper bar	II
	Casing	I
Mooring winches	Gear wheel, shaft, foundation bolt	II
	Casing	I
Winch hydraulic motors		II
Winch controls	Hydraulics	II
Bollards		III
Fairleads/bits		II
Anchor	Crown/head, shackle and shank	II
	Crown/head pin and shackle/swivel pin	I
Anchor lashing		II
Chain stopper		II
Emergency towing system①		II
Exposed weight-bearing structures and machinery components, cargo securing arrangements		II
Lifting appliances, boat davits/boat hooks		II
Others		
Ventilator, small hatch cover, manhole cover		I

Note: ① When emergency towing arrangements are used as bollards, the material is to be class III.

23.2.3.3 Charpy V-notch impact tests for materials of the piping systems (including pipes, valves and fittings) for machinery equipment and systems exposed to low air temperature environments are to be in accordance with the requirements as given in Tables 23.2.3.3(1) to 23.2.3.3(3).

23.2.3.4 The material classes specified in Tables 23.2.3.3(1) to 23.2.3.3(3) are opposite to the classes of piping in Section 1, Chapter 2, PART THREE of the Rules, i.e. for class I piping, the material class of the piping is to be class III.

23.2.3.5 In general, the Charpy V-notch impact energy of piping materials exposed to low air temperature environments is not to be less than 27 J.

Impact Testing Temperature Requirements for Class I in Low Air Temperature Environments

Table 23.2.3.3(1)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	+20	+20	+20	0	-20	-20
10<t≤15	+20	+20	0	-20	-20	-20
15<t≤20	0	0	0	-20	-20	-40
20<t≤25	0	0	-20	-20	-20	-40
25<t≤30	0	-20	-20	-20	-40	-40
30<t≤35	-20	-20	-20	-20	-40	-40
35<t≤45	-20	-20	-20	-40	-40	-40
45<t≤50	-20	-20	-40	-40	-60	-60

Impact Testing Temperature Requirements for Class II in Low Air Temperature Environments

Table 23.2.3.3(2)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	+20	+20	0	-20	-20	-40
10<*t*≤20	0	0	-20	-20	-40	-40
20<*t*≤30	0	-20	-20	-40	-40	-60
30<*t*≤40	-20	-20	-40	-40	-60	-60
40<*t*≤45	-20	-20	-40	-60	-60	–
45<*t*≤50	-40	-40	-40	-60	-60	–

Impact Testing Temperature Requirements for Class III in Low Air Temperature Environments

Table 23.2.3.3(3)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	0	0	-20	-20	-40	-40
10<*t*≤20	0	-20	-20	-40	-40	-60
20<*t*≤25	-20	-20	-40	-40	-60	-60
25<*t*≤30	-20	-40	-40	-40	-60	-60
30<*t*≤35	-40	-40	-40	-60	-60	–
35<*t*≤40	-40	-40	-40	-60	-60	–
40<*t*≤45	-40	-40	-60	-60	-60	–
45<*t*≤50	-40	-40	-60	-60	–	–

23.2.3.6 Steel forgings and castings used for exposed machinery and system components are to be made of killed steel and to comply with the relevant requirements of Chapters 5 and 6, PART ONE of ISC Rules for Materials and Welding.

23.2.3.7 The impact testing temperature for steel forgings and castings is given in Table 23.2.3.7. For steel the yield strength of which is less than 305 N/mm^2, the minimum average impact energy is to be 27 J; for steel the yield strength of which is equal to or greater than 305 N/mm^2, the minimum average impact energy is to be 34 J.

Impact Testing Temperature Requirements for Steel Forgings and Castings in Low Air Temperature Environments **Table 23.2.3.7**

Class	Design service temperature (℃)			
	-23~-27℃	-28~-32℃	-33~-38℃	≤-39℃
Class I or II	-20	-20	-40	Specially considered
Class III	-20	-40	-40	
Note: For manufacturing and installation of non-welded members, the testing temperature may increase by 20℃, but not more than 0℃.				

23.2.4 Welding

23.2.4.1 The welding technical requirements for hull structural members and machinery structural members/components are to be referred to in Section 2, Chapter 5, PART THREE of ISC Rules for Materials and Welding.

23.2.4.2 The selection of welding consumables are to satisfy the performance requirements of the pieces to be welded. For welding of high strength quenched and tempered steel, low hydrogen welding consumables are to be used.

23.2.4.3 The finished welds are to comply with the rules requirements.

Section 3 SHIP ARRANGEMENTS

23.3.1 General requirements

23.3.1.1 Equipment and areas that require anti-icing/anti-freezing measures are as far as possible to be situated in protected locations, such as enclosed spaces, semi-enclosed spaces or covered by curtains.

23.3.1.2 For structures, equipment and pipes, the heating capacity for anti-icing and anti-freezing arrangements is to be sufficient to prevent icing or freezing in low air temperature environments, the arrangements are to be able to maintain a surface temperature of at least 3 ℃ under the minimum anticipated temperature.

23.3.1.3 In anti-icing and anti-freezing arrangements using heating, special attention is to be paid to the heat transfer from the heating cables or pipes to the equipment or structure to be heated. The spacing and fastening of heating cables or pipes are to be appropriate for efficient heating to keep the equipment or structure ice-free under the minimum anticipated temperature.

23.3.1.4 For anti-icing and de-icing arrangements applying heating by fluids in pipes, the installation is to ensure that the heating fluid maintains its heating effectiveness under the minimum anticipated temperature.

23.3.2 Accommodation

23.3.2.1 Accommodation heating systems are to be capable of maintaining a reasonable internal temperature in all spaces normally occupied when the ship is at sea. Supplementary heaters may also be used in accommodation and other manned spaces in addition to the air conditioning heating system specified in 23.6.4.12.

23.3.2.2 Heating arrangements are to be provided for the following spaces, but not limited to, containing machinery and equipment for essential or emergency services to satisfy the service demands of such spaces:

(1) navigation bridge;
(2) radio room;
(3) hospital room (including sick bay);
(4) battery room;
(5) mooring rope stores (including the bosun's store);
(6) observation/security cabins (where fitted);
(7) enclosed forecastle/sheltered deck (where fitted);
(8) under-deck passageways (where fitted);
(9) main engine and auxiliary machinery space(s) (including individually arranged main generator room);
(10) azimuth thruster space(s) (including pods);
(11) boiler room;
(12) workshop room and store(s);
(13) engine control room;
(14) switchboard room;
(15) steering gear room;

(16) bow thruster(s) room;
(17) emergency generator room;
(18) fire control station(s);
(19) fire-fighting appliances stores;
(20) stores for de-icing, anti-freezing measures (where fitted);
(21) emergency fire pump-room.
In general, fixed heating arrangements are to be used. For items (6), (7), (10) to (13) above, when the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.
23.3.2.3 Accommodation requiring heating arrangements to maintain a reasonable internal temperature is to be provided with a fixed thermometer.

23.3.3 Tanks
23.3.3.1 The ship is to have an appropriate arrangement to prevent the surfaces in ballast tanks, fresh water tanks and other relevant tanks from freezing over considering the minimum anticipated temperature.
23.3.3.2 Tank arrangements are to be such that fuel oil tanks are to be maintained 10℃ above the fuel's pour point and water tanks are to be maintained not lower than 2 ℃ under the minimum anticipated temperature.
23.3.3.3 Different anti-freezing measures are to be used depending on conditions, such as continuous circulation, bubble turbulence or convection-inducing systems, etc.; where the design service temperature is below -40℃, convection-inducing measures are to be used, such as a vertical heating coil.
23.3.3.4 Level gauging arrangements of the tank is to function under the minimum anticipated temperature.
23.3.3.5 Where the ballast tank is fully below the light service waterline or lower ice waterline, whichever is lower, and where the fresh water tank is not adjacent to the shell or deck and is located in the heated area, anti-freezing measures may not be provided, unless specified otherwise.

23.3.4 Superstructures and deckhouses
23.3.4.1 For ships operating in polar waters, the bridge wings are to be enclosed and both sides are to be visible without opening the bridge doors and windows. Additional conning positions, if any, are to be enclosed.
23.3.4.2 Bridge windows are to be fitted with heating and cleaning systems and are to function under the minimum anticipated temperature. Where the water flushing system is fitted, measures are to be taken to prevent pipelines and fittings from freezing and thus becoming inoperable.
23.3.4.3 Navigation bridge doors and the adjacent deck areas are to be so arranged as to prevent ice and snow accretion.
23.3.4.4 Cargo control room sidescuttles (including window wipers) are to be heated as required and external access for cleaning is to be provided.
23.3.4.5 At least one of the Master's cabin windows is to have a heating arrangement for a view over the cargo deck where necessary.
23.3.4.6 Windows in accommodation spaces are generally to be double-glazed except for those on ships operating in low air temperature environments occasionally or for a short period.
23.3.4.7 Exterior stairs and railings not forming the escape routes are to be provided with anti-icing or de-icing protection.

23.3.5 Helicopter decks
23.3.5.1 Helicopter decks or hovering areas, if provided, are to be provided with de-icing measures.

Section 4 STABILITY

23.4.1 General requirements
23.4.1.1 Ships operating in low temperature environments① are to have sufficient stability when subject to ice accretion under the minimum anticipated temperature.
23.4.1.2 Ships operating in low temperature environments are to be:
(1) designed to minimize the accretion of ice;

① Low temperature environments mean environments where ice accretion is possible when the air temperature is below 0℃.

(2) equipped with such means for removing ice; for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections;
(3) monitored for ice accretion during operation and appropriate measures are to be taken to ensure that ice accretion allowance does not exceed the value specified in the Stability Manuel.

23.4.2 Intact stability

23.4.2.1 Intact stability of ships when subject to ice accretion is to comply with the relevant requirements in Section 9, Chapter 1, PART TWO of the Rules.

23.4.2.2 For ships operating in low air temperature environments, the following icing allowances are to be considered in the stability calculation:
(1) 30 kg/m^2 on exposed decks and gangways;
(2) 7.5 kg/m^2 for projected lateral area of each side of the vessel above the water plane; and
(3) the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of vessels having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

23.4.2.3 The Stability Manuel is to contain the information on ice accretion allowance in the stability calculation.

Section 5 WATERTIGHT AND WEATHERTIGHT INTEGRITY

23.5.1 General requirements

23.5.1.1 For ships operating in low temperature environments, all closing appliances and doors related to watertight and weathertight integrity onboard are to be operable.

23.5.2 Hatches, side doors and cargo loading doors

23.5.2.1 For ships intended to operate in low air temperature environments (except for those navigating in the cold areas occasionally or for a short period), the following requirements are also to be complied with:
(1) If the hatches or doors are hydraulically operated, measures are to be taken to prevent liquid from freezing or excessive viscosity.
(2) Watertight and weathertight doors, hatches and closing devices not in habitable environments but required for use while at sea are to be so designed as being operable by persons wearing heavy winter clothes and thick mittens.

23.5.2.2 Ramp doors and side doors are to be provided with means to remove ice accretion around hatches and doors.

23.5.3 Freeing ports, scuppers, discharges and inlets

23.5.3.1 For ships intended to operate in low air temperature environments, freeing ports, scuppers, discharges and inlets are to be kept clear.

23.5.3.2 Freeing ports are to comply with the following requirements:
(1) freeing ports are to be fitted with anti-icing protection;
(2) if a shutter is fitted on the freeing port, it is to be provided with heating sufficient for maintaining its opening ability;
(3) increasing the freeing port area by 30% is accepted as an alternative to heating.

23.5.3.3 For decks, passageways and muster areas that are required to be kept ice-free, the scuppers and discharges in such spaces are to be provided with anti-freezing protection.

Section 6 MACHINERY INSTALLATIONS

23.6.1 General requirements

23.6.1.1 All machinery, equipment and systems, including pipes and cabling, are to be located inside spaces as far as practicable to minimize exposure to low air temperature environments where ice and snow accretion are likely to occur.

23.6.1.2 Main and auxiliary machinery and exposed essential machinery equipment are to be capable of operating satisfactorily under the minimum anticipated temperature.

23.6.1.3 Each machinery and system on board ships are to be provided with the following appropriate protection methods to prevent effects of low temperatures and ice accretion:
(1) heating (for space and/or dedicated arrangements for equipment/systems);
(2) de-icing equipment;
(3) covers (where PVC covers or other water resistant materials are used, they are to be fixed firmly to prevent unintended removal in severe weather conditions);
(4) drainage;
(5) insulation;
(6) selection of materials;
(7) selection of lubricants, oils, hydraulics and greases, etc.
23.6.1.4 Where heating arrangements are provided, they are to be fitted with the following:
(1) means for ascertaining the temperature;
(2) for systems where heating arrangements could result in excessively high temperatures or pressures being generated, that may cause damage, malfunction or braking of equipment, there are to be arrangements provided for cutting off the heating;
(3) appropriate control arrangements;
(4) indication of the system(s) operation;
(5) where failure of a heating arrangement could result in a hazardous situation, an alarm is to be activated.

23.6.2 Main and auxiliary machinery
23.6.2.1 To ensure the starting capacity of ships from the dead-ship condition, due consideration is to be given to the impacts of the minimum anticipated temperature on the relevant machinery and electrical equipment.
23.6.2.2 The combustion air system of the prime mover is to be suitable for the minimum anticipated temperature.
(1) The arrangements for air supply to main propulsion, main generators and emergency generators are to ensure that the engine manufacturer's specification for air intake temperature is complied with.
(2) Turbochargers and the associated combustion air system for internal combustion engines are to be so designed as to obtain surge-free operation throughout the range of ambient air temperatures in which the ship is expected to operate.
(3) For ships operating in polar waters all year round, where the design service temperature is below -40℃, the combustion air is to be led directly from the weather to the engines having a rated power of 100 kW and over by way of ducting or other suitable means.
(4) The combustion air intakes are to be located on both sides of the ship and so arranged as to prevent the recirculation of engine exhaust gases into the combustion air intakes, ice/snow accretion and blockage of the duct.
(5) Combustion air for other internal combustion engines used as prime movers is to be provided in accordance with the manufacturer’s recommendations. The details and arrangements will be subject to special consideration of ISC.
23.6.2.3 The lubricating oil of the engine is to be maintained at the proper minimum temperature in accordance with the manufacturer’s recommendations to allow equipment start-up. The use of steam heating coils within prime mover sump tanks is not permitted.
23.6.2.4 Under the anticipated seawater temperature condition, oil-lubricated bearings are to be provided with means to heat the lubricating oil to maintain viscosity in accordance with the bearing manufacturer’s requirements; water-lubricated bearings are to be suitable for continuous operation in low temperatures.
23.6.2.5 Steering gear components are to be provided with greases or lubricating oils suitable for low temperature unless they are arranged in positive temperature spaces.
23.6.2.6 Azimuth propulsion systems as well as ship steering systems (such as pods) are to be provided with suitable provisions to prevent freezing, including heating arrangements, suitable lubricating oils, hydraulic oils and antifreeze.
23.6.2.7 Where an auxiliary boiler serves anti-cold climate arrangements simultaneously, its capacity is to satisfy the demand under the minimum anticipated temperature; for ships operating in polar waters all year round, where the design service temperature is below -40 ℃ , at least two auxiliary boilers are to be provided, either of which is to satisfy the demand of the ship.

23.6.3 Deck machinery
23.6.3.1 Exposed control panels of deck machinery are to be provided with protective covers or heating arrangements for anti-freezing protection.

23.6.3.2 Where ice accretion occurs to cranes on deck in low air temperature environments, the cranes are to be able to withstand ice accretion allowance in the stowed and operating conditions as applicable. Crane foundations and supporting structures are also to be able to support a crane with the ice accretion allowance under consideration above.
23.6.3.3 Means are to be provided for habitable working conditions in exposed crane cabs, where fitted, by providing internal space heating arrangements. Cab windows are to be provided with heating arrangements to prevent icing.
23.6.3.4 Suitable provisions for cold start at the design service temperature of exposed deck cranes are to be provided. Suitable lubricating oils and greases, circulation facilities for hydraulic oils and a flushing system for the hydraulic oil are to be provided.
23.6.3.5 The anchor windlass and exposed windlass controls are to be provided with appropriate covers or heating arrangements for anti-icing protection. Alternatively, they are to be arranged in enclosed or semi-enclosed deck areas. Anchor chains are to be capable of being de-iced manually.
23.6.3.6 The hawse pipes are to be provided with anti-freezing protection or de-icing protection by steam or hot water.
23.6.3.7 Hawse pipe wash lines are to be provided with continuous circulation or heating arrangements for anti-freezing protection of water in the pipes.
23.6.3.8 Mooring winches are to be provided with suitable covers or heating arrangements for anti-icing protection. De-icing measures are to be arranged in the vicinity of mooring winches.
23.6.3.9 The foundations of anchor windlass and mooring winches may be cast by epoxy resin, the minimum anticipated temperature is to be taken into account for selection of the epoxy resin.

23.6.4 Piping systems
23.6.4.1 Piping systems are to be so designed as to minimize exposure of crew to low air temperature environments during normal operation and routine maintenance.
23.6.4.2 The possibility of ingress of ice/snow and the adverse impacts of low air temperature and ice accretion are to be taken into account for piping systems located in exposed or low temperature spaces. Exposed piping systems are to be suitable for the minimum anticipated temperature.
(1) Hoses in low air temperature environments are to maintain their flexibility and tightness.
(2) Exposed valves are to avoid freezing of fluids on either side of the valve and to prevent the accumulation of snow and spray ice.
(3) Piping components located in exposed or low temperature spaces, such as valve control units, manifolds, vents, gasket seals, and thermal instruments such as indicators, sensors and other fittings, are to be provided with anti-icing, anti-freezing protection or other means to provide for continued functionality.
(4) Pipes in which fluids are liable to freezing are to be so arranged as to be drained effectively, otherwise means are to be provided for anti-freezing protection.
(5) Overboard discharge outlets are normally to be arranged below the waterline.
(6) Overboard discharge valves arranged in low temperature spaces or above the waterline are to be provided with low pressure steam connections for clearing purposes, unless other anti-freezing measures are provided.
(7) Due consideration is to be given to the thermal expansion and cold contraction impacts on pipes due to temperature difference for piping arrangements in exposed and low temperature spaces.
23.6.4.3 Vent piping systems and sounding pipes are to maintain functionality in low air temperature environments.
(1) For air pipes and pipe heads arranged in exposed or low temperature spaces, measures are to be taken to prevent blockage due to internal humidity freezing.
(2) Exposed air vent pipe heads are to be provided with anti-icing measures against blockage, such as heat tracing or protective cover; where protective covers are provided against icing, the covers are not to interfere with the free flow of air through the vent openings.
(3) Sounding pipes of tanks are to be provided with anti-freezing measures for ready availability.
(4) Where the tank is provided with heating arrangements, anti-freezing measures may be exempted for the vent piping system and sounding pipe upon calculation.
23.6.4.4 Ballast water piping systems are to maintain functionality in low air temperature environments.
(1) The use of gray cast iron material for piping, valves and fittings is prohibited.
(2) Where local freezing of ballast tanks is unavoidable, GRP piping and other system components in the tanks likely to be damaged by fallen ice hitting are to be suitably protected.
(3) Where sea chests are provided for ballast water piping system separately, direct steam connections to the sea chests are to be provided for de-icing purposes; alternatively, a sea bay and heating arrangements may be used.

(4) Sea inlet valves are to be provided with low pressure steam connection for clearing purposes.
(5) Overboard discharge outlets are generally not to be above the waterline; where they must be above the waterline, suitable heating arrangements are to be provided for ballast water discharge pipes.
(6) Where the design service temperature is below -40℃, suitable heating arrangements are to be provided for ballast water discharge pipes.
23.6.4.5 Fresh water piping systems in low air temperature environments are to be provided with suitable anti-freezing arrangements.
(1) Fresh water pipes are to be arranged in positive temperature spaces as far as practicable and are to be thermally insulated or heat traced when running through low temperature spaces.
(2) Exposed sections of fresh water lines are to be fitted with an isolating valve located inside a positive temperature space such that the exposed length can be drained, and in general a dry air blow connection is to be provided at the most forward end.
(3) Fresh water generation systems' inlet water temperatures are to comply with the manufacturer's requirements.
23.6.4.6 Drainage piping systems are to maintain functionality in low air temperature environments.
(1) Drainage pipes are to be arranged in positive temperature spaces as far as practicable or heat traced.
23.6.4.7 Fuel oil piping systems are to maintain functionality in low air temperature environments.
(1) In addition to adding additives to fuel oil, where necessary, fuel oil tanks for engines and boilers are to be provided with heating coils to ensure continuous supply of fuel oil in the minimum anticipated temperature.
(2) Where ships need to be filled with fuel oil in low air temperature environments, fuel oil filling stations are to be located in an area sheltered from the weather and easy for access and operation. For fuel oil filling pipes located on the deck, alternative arrangements to protect the filling pipes are to be provided such as a removable or hinged cover may be installed.
(3) Where the design service temperature is below -25℃, fuel oil filling pipes and transfer pipes arranged in exposed and low temperature spaces are to be heat traced and thermally insulated.
23.6.4.8 Seawater cooling piping systems are to ensure normal seawater supply in the anticipated environments.
(1) At least one sea chest is arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.
(2) Sea chest valves are to be provided with low pressure steam connection for clearing purposes.
(3) Where the design service temperature is below -40℃, cooling water discharge pipes are to be provided with suitable heating arrangements.
(4) As an alternative to (1), (2) and (3) above, ballast water may be circulated as cooling water for main and auxiliary engines, and relevant heat balance calculations are to be submitted.
23.6.4.9 Compressed air piping systems are to ensure supply of sufficiently dry compressed air to essential systems in low air temperature environments.
(1) Compressed air for low temperature spaces is to have a dew point not higher than the design service temperature, but at least as low as -25℃.
(2) Compressed air supplying control air to exposed facilities is to have a dew point not higher than the minimum anticipated temperature.
(3) Where the design service temperature is not lower than -25℃, heating arrangements may be used as an alternative to (1) and (2) above; where the design service temperature is lower than -25 ℃ , heating arrangements are to be provided for control air.
(4) Compressed air pipes arranged on exposed decks are to be provided with drainage valves at the lowest position.
23.6.4.10 Hydraulic piping systems are to maintain functionality in low air temperature environments.
(1) Hydraulic oil is to either be of a type that maintains an acceptable viscosity, or the hydraulic system is to have heating or circulation arrangements to keep fluids at an appropriate temperature to ensure the operability of the essential systems they serve.
(2) As far as practicable, hydraulic oil power packs are to be sited in positive temperature spaces. Where this is not practicable, the hydraulic oil and piping system are to be suitable for operation under the minimum anticipated temperature.
(3) Exposed control stand valves for hydraulic oil lines used for remote control are to be provided with heating arrangements for anti-freezing protection of the mechanism.
(4) Where the design service temperature is lower than -25 ℃ , heating arrangements are to be provided under the bottom of hydraulic oil tank in low temperature spaces; where the design service temperature is lower than -40℃, hydraulic pipes in low temperature spaces are also to be thermally insulated or heated.

23.6.4.11 Steam piping systems are to maintain functionality in low air temperature environments.
(1) Means are to be provided for anti-freezing protection of condensate in exposed steam pipes, by thermal insulation or by compressed air blow when not in use.
23.6.4.12 HVAC systems are to operate effectively under the anticipated design service temperature.
(1) Accommodation spaces are to be heated at least to 18 ℃ under the anticipated design service temperature and maintained at this temperature.
(2) The maximum fresh air ratio in accommodation spaces is to be 0.5.
(3) The relative humidity of spaces fitted with HVAC systems is to be maintained in the range between 30% and 70%.
(4) Condensate on the inner bulkheads of accommodation spaces is to be kept at a minimum and effective condensate drainage systems are to be provided.
(5) Condensate on observation windows of the navigation bridge and cargo control room are to be kept at a minimum.
(6) Closing appliances for ventilation inlets and outlets are to be suitably arranged to prevent disturbance by snow and ice accretion and to maintain the effectiveness of air circulation.

23.6.5 Electrical equipment
23.6.5.1 In addition to complying with the requirements of Section 1, Chapter 2, PART FOUR of the Rules, the capacity of the main power source is to be sufficient to supply the air-conditioning system and heating arrangements provided to keep spaces at positive temperatures.
23.6.5.2 In addition to complying with the requirements of Section 2, Chapter 2, PART FOUR of the Rules, the emergency power source is to supply the following equipment and ensure 18 h for cargo ships and 36 h for passenger ships:
(1) power to the heating arrangements in the following spaces:
① navigation bridge;
② radio room;
③ engine room centralized control room;
④ workshop;
⑤ cargo control room;
⑥ fire control room;
⑦ hospital room;
⑧ at least one public space of cargo ships (such as crew mess room and recreation room), one or several public spaces of passenger ships sufficient to hold all passengers and crew;
⑨ battery room;
⑩ emergency generator room;
⑪ emergency fire pump room;
(2) heat tracing for any piping associated with the emergency consumer;
(3) auxiliary boiler, if provided, with the control, monitoring and safety system.
23.6.5.3 Generators and electric motors installed on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements as well as lubricating oil suitable for the design service temperature if the bearings require forced lubrication or pre-lubrication.
23.6.5.4 Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.
23.6.5.5 Electric cables on exposed decks and in low temperature spaces are to be type approved according to the design service temperature. Electric cables on exposed decks are to be protected by metallic pipes or lines or sheaths.
23.6.5.6 Where electrical equipment is used to heat battery rooms, the explosion group and temperature class of equipment is not to be lower than IIC T1.
23.6.5.7 Illumination lights and navigation lights installed on exposed decks are to be suitable for the design service temperature. Where lights mentioned above cannot generate sufficient heat to keep the light fixture ice-free, they are to be readily accessible and suitable for manual de-icing, or heating arrangements are to be provided.
23.6.5.8 Where closed circuit television systems are fitted on exposed decks, these are to be provided with heating arrangements or covers, to prevent the equipment from damages or abnormal operation due to freezing.

Section 7 FIRE FIGHTING

23.7.1 General requirements

23.7.1.1 Fire-fighting systems and appliances are to be readily available at the design service temperature.

23.7.1.2 Fire mains and fire-fighting system piping are to be provided with the following anti-freezing protection, but not limited to:

(1) located in a heated passageway; or

(2) provided with heat tracing; or

(3) arranged as a dry system.

23.7.1.3 Where piping is arranged as a dry system, it is to be drained after use. Drains are to be located at the lowest points in the system, and connection means of compressed air vent pipe are to be provided at the end of the pipe other than the end where the drains are located in order to maintain the line drying. The piping layout is to ensure that all water will drain to them without being trapped in U-bends, low points or dead-ends.

23.7.1.4 For the fire-fighting system, isolating valves are to be provided between pipelines on exposed deck and those in the heated spaces. The isolating valves in exposed locations are to be provided with anti-icing protection and located in areas where it is easily accessible.

23.7.1.5 Fire extinguishing agents (foams, powders, gases) are to be rated for operation at the design service temperature.

23.7.1.6 Hydrants are to be provided with anti-icing and anti-freezing protection. The stowage positions for fire hoses and nozzles are to be provided with anti-icing and anti-freezing protection, the hoses and nozzles are to be dried immediately after use.

23.7.1.7 Portable extinguishers located in exposed and low temperature spaces are to be rated for operation at the design service temperature. The storage facilities of the portable extinguishers are to be provided with anti-icing protection and readily accessible.

23.7.1.8 All two-way portable radiocommunication equipment are to be operable at the design service temperature.

23.7.2 Fire pumps

23.7.2.1 All fire pumps, including emergency fire pumps, are to be installed in positive temperature spaces to ensure the ship's normal operation of the fire-fighting system under the minimum anticipated temperature.

23.7.2.2 Main fire pumps, if provided with separate sea chests, are arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.

23.7.2.3 Sea chests of emergency fire pumps are to be provided with means for heating, insulation or low pressure steam connection to prevent the blockage by floating ice.

23.7.3 Fire-fighter's outfits

23.7.3.1 Fire-fighter's outfits are to be stowed in easily accessible positive temperature spaces.

23.7.4 Escape routes

23.7.4.1 Essential emergency routes, such as escape routes, muster areas, lifeboat embarkation areas, are to be provided with anti-icing protection. Where exposed decks of the ship have no anti-icing requirements, de-icing tools to remove ice and snow accretion are to be provided to ensure the safety of persons onboard. Gangways and ramps are to be provided with de-icing arrangements.

23.7.4.2 Overhead structures are to be provided with de-icing or other arrangements to prevent injuries to persons or damages to essential safety equipment/structures by fallen ice.

23.7.4.3 Escape routes are to be provided with anti-icing protection to ensure that the escape routes are ice-free or providing a minimum ice-free width of 700 mm, enabling the use of at least one railing. Railings that are important as hand-holds (stairs, escape ways) are to have anti-icing protection. Railings that function only as barriers, but are not intended as handholds, may be provided with de-icing arrangements only.

23.7.4.4 External handrails on routes, stairways and ladders, if provided with heating arrangements for anti-icing protection, are to be fitted with arrangements to cut off automatically in the event of excessively high temperatures to prevent injuries to persons when in contact.

23.7.4.5 Escape routes are to be so dimensioned as not to hinder passage for persons wearing polar clothing.

23.7.4.6 Exits forming escape routes are to be provided with anti-icing measures and door seals are to be suitable for the design service temperature.

Section 8 LIFE-SAVING APPLIANCES AND ARRANGEMENTS

23.8.1 General requirements

23.8.1.1 The performance standards of life-saving appliances and arrangements are to comply with the requirements of this Section in addition to the provisions of the International Life-Saving Appliance (LSA) Code.

23.8.1.2 Life-saving appliances and arrangements are to be fully functional at the design service temperature (DST).

23.8.1.3 For ships operating in polar waters, life-saving appliances and arrangements are to be fully operable at the design service temperature (DST) during the maximum expected rescue time.

23.8.1.4 For ships the design service temperature (DST) of which is below -30℃, the muster station is to be located inside space.

23.8.1.5 The bridge and exposed deck life-buoys are to be provided with anti-icing protection and be arranged such that it is immediately deployable by the crew.

23.8.2 Lifeboats

23.8.2.1 Lifeboats are to be of totally enclosed type. The capacity of the lifeboats is to be sized for persons dressed in heat-insulated immersion suits or anti-cold climate clothing.

23.8.2.2 Lifeboat engines are to start within 2 min at the design service temperature (DST). Two separate power sources are to be provided for the start-up of lifeboat engines. Lifeboat engine batteries are to be suitable for low temperature conditions.

23.8.2.3 The cooling system for lifeboat engines is to ensure that the engines are operable at the design service temperature (DST).

23.8.2.4 Cooling water, fuel and lubricating oils for engines are to be suitable for engine operation at the design service temperature (DST).

23.8.2.5 Heating arrangements are to be provided in way of the lifeboat doors.

23.8.2.6 Heating arrangements are to be provided for lifeboat windows at the operating position, and measures are to be taken to maintain clear field of vision.

23.8.2.7 Consideration is to be given to the capacity of drinking water containers to be suitable to allow for expansion due to freezing.

23.8.2.8 Additional rations, equaling to at least 30% of the amount specified in the LSA Code, are to be provided for ships usually operating in low air temperature environments.

23.8.2.9 The release mechanism of lifeboats is to be provided with heating or other arrangements to ensure safe release at the design service temperature (DST).

23.8.2.10 Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.

23.8.3 Rescue boats

23.8.3.1 Rescue boats provided onboard are to be rigid rescue boats.

23.8.3.2 Cooling water, fuel and lubricating oils for engines are to be suitable for engine operation at the design service temperature (DST).

23.8.4 Liferafts

23.8.4.1 Where the design service temperature (DST) is blow -30℃, the inflation of inflatable liferafts is to be completed within a period of 3 min.

23.8.4.2 Where the design service temperature (DST) is below -30 ℃ , the container and hydrostatic release mechanism for liferafts are to be provided with heating or other arrangements to ensure easy launching, inflation and release of the liferafts at the design service temperature (DST).

23.8.4.3 Where manual inflation pumps for inflatable liferafts are provided onboard, the pumps are to be stowed in positive temperature spaces in the vicinity of the inflatable liferafts.

23.8.4.4 Additional rations, equaling to at least 30% of the amount specified in the LSA Code, are to be provided for ships usually operating in low air temperature environments.

23.8.4.5 Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.

23.8.5 Launching appliances for survival craft and rescue boats

23.8.5.1 Hydraulic oil and lubricating oil for launching and embarkation appliances are to be suitable for operation at the design service temperature (DST). Greases suitable for operation in low temperatures are to be provided for davits and release hooks.
23.8.5.2 Electric motors, winches and automatic release hooks are to have moveable covers; where the design service temperature (DST) is below -40℃, heating arrangements are to be provided.
23.8.5.3 Electric motors, hydraulic units, winches, brakes and other components of launching appliance are to be operable at the design service temperature (DST). Appropriate tests are to be carried out to verify their operability.
23.8.5.4 Other members of launching appliances, such as winches, sheaves, winch brakes, etc. are to be provided with heating or other arrangements to ensure safe launching of survival craft and rescue boats at the design service temperature (DST).
23.8.5.5 The stowage positions for embarkation ladders are to be provided with covers or heating arrangements to prevent ice accretion.

23.8.6 Communication
23.8.6.1 Fixed two-way VHF radio installations onboard lifeboats are to be capable of operation at the design service temperature (DST).
23.8.6.2 For ships operating in polar waters, signal appliances fitted on all survival craft and rescue boats are to be operable at the design service temperature (DST).

Section 9 NAVIGATIONAL SAFETY

23.9.1 General requirements
23.9.1.1 Radio installations and navigational equipment installed on exposed decks are to be type tested according to the design service temperature.
23.9.1.2 Arrangements are to be made to prevent damage to antennae due to accumulation of ice and snow except for whip type antennae. Antennae may be heated or placed in heated domes, or in a place easily accessible for manual de-icing.
23.9.1.3 The movement of rotating antennae (e.g., radar, Inmarsat B and F) is not to be inhibited by snow or ice.

23.9.2 Navigational equipment
23.9.2.1 Ships operating in polar waters are to be provided with two searchlights that can rotate 360° horizontally and be remotely operated from the wheelhouse. Searchlight housing is to use heated glass or be provided with covers to prevent accumulation of ice and snow. The rotation mechanism is to be provided with anti-icing protection.
23.9.2.2 Magnetic compasses installed on exposed decks are to be provided with protective covers.

Section 10 SHIP TYPE SPECIFIC ADDITIONAL REQUIREMENTS

23.10.1 General requirements
23.10.1.1 The requirements of this Section apply respectively to different ship types, including oil tanker/chemical tanker, liquefied gas carrier, bulk carrier/ore carrier, offshore supply vessel and other special ship types.
23.10.1.2 The above-mentioned ship types are to comply with the following specific requirements in addition to the applicable requirements in Sections 1 to 9.

23.10.2 Bulk carrier/Ore carrier
23.10.2.1 Bulk carriers and ore carriers applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.2.2 Ballast tanks and piping are to comply with the following additional requirements:
(1) If fitted, piping connecting the upper wing tanks and lower wing tanks is to have anti-freezing protection. If a steam heating coil is fitted on the surface of this connecting pipe, it is to be protected so as to avoid being damaged due to cargo loading and unloading operations.

(2) For double bottom tanks and lower wing tanks that may be exposed to the design service temperature, ballast water inside such tanks is to be prevented from freezing. Water ingress alarms of cargo holds and bilge piping are to take the impacts of low temperature into account.
(3) If an air bubble system or heating coil system is provided in the lower wing tank for anti-freezing protection, no additional anti-freezing protection will be required for the upper wing tank and connecting pipe.
23.10.2.3 Where cargo loading and unloading operations will be carried out in low air temperature environments for long duration, the low-temperature performance of materials of inner bottom plating of double bottom tanks and sloping bottom plating of lower wing tanks is to be considered in the design.

23.10.3 Oil tanker/Chemical tanker
23.10.3.1 Oil tankers and chemical tankers applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.3.2 In addition to the provisions of 23.3.2.2, compartments requiring additional heating arrangements are to include cargo control rooms, cargo pump rooms, oil discharge monitoring equipment rooms (where fitted) as well as compressor rooms, motor rooms and cargo transfer observation stations that may be fitted. For cargo control rooms and cargo transfer observation stations, where the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.
23.10.3.3 The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.
23.10.3.4 Piping systems arranged on exposed decks are to comply with the following additional requirements:
(1) For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance.
(2) The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.
(3) Means are to be provided for anti-freezing protection of cargo fluids within exposed pipes, particularly for small bore pipes such as cargo drain and pressure gauge lines. When the design service temperature is below -25℃, the cargo and stripping lines on exposed deck are to be provided with suitable heat tracing and thermal insulation.
(4) Exposed inert gas systems and relevant equipment are to comply with the following requirements:
① the inert gas system scrubber is to be located in a compartment not affected by the weather. The cooling water system for inert gas scrubber is to be provided with suitable means of anti-freezing protection;
② means for the deck water seal are to be provided to ensure the added fluid to be free from freezing. Proper application of antifreeze or provision of heating arrangements may be used;
③ the exposed water supply and discharge lines to the deck water seal are to be provided with heating arrangements or thermal insulation with continuous circulation;
④ the non-return valve for the deck water seal is to be provided with suitable drainage and a set of control handles for testing;
⑤ the pressure/vacuum breakers are to be suitable for the minimum anticipated temperature. Proper application of antifreeze or provision of heating arrangements may be used;
⑥ drainage lines are to be thermally insulated;
⑦ equipment requiring de-icing maintenance are to be grouped together as far as practicable and readily accessible.
(5) Pressure/vacuum valves are to be provided with suitable anti-icing protection and de-icing measures so as to keep the valves readily operable.
(6) De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.
23.10.3.5 The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.
23.10.3.6 Monitoring systems are to comply with the following requirements:
(1) Heat tracing systems are to be provided with the temperature monitoring function so that any system failure or temperature exceeding limits will result in an alarm at the manned control station.

(2) The following instruments and equipment, when exposed to the low air temperature environments, are to be provided with heat tracing systems:

① level indicators for cargo tanks;

② overflow control;

③ pressure gauges;

④ temperature-indicating devices;

⑤ instrumentation for gas detection systems.

23.10.4 Liquefied gas carrier (LPG/LNG)

23.10.4.1 LPG and LNG carriers applying for Anti-Cold Climate notations are to comply with the following requirements.

23.10.4.2 For cargo containment system or any cover for the containment system exposed outside the hull, the requirements of 4.3.4 in Chapter 4, PART THREE of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with, taking into account the following ice and snow loads on the system or the cover in low air temperature environments:

(1) static load of ice and snow;

(2) dynamic load from sliding or dropped ice.

23.10.4.3 In addition to the provisions of 23.3.2.2, compartments requiring additional heating arrangements are to include cargo control rooms, cargo pump rooms, nitrogen storage rooms as well as compressor rooms, motor rooms and cargo transfer observation stations that may be fitted. For cargo control rooms and cargo transfer observation stations, where the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.

23.10.4.4 The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.

23.10.4.5 Exposed cargo related systems are to function properly in low air temperature environments and under ice/snow accretion conditions:

(1) For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance.

(2) The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.

(3) Where LNG carriers utilize cargo boil-off as fuel for propulsion power, particularly operating in the "gas only mode", the normal rate of boil-off (NBOR) is to take into account the minimum anticipated temperature, and the provisions for forced boil-off are to be adequate.

(4) Exposed safety relief valves and other valves are to be arranged in such a way as to provide their local and remote activation under all circumstances. De-icing and heat tracing arrangements are to be provided for the valves. Valve actuators with local position indicators are to be of the enclosed type.

(5) Emergency shutdown (ESD) valves are to be provided with anti-icing protection.

(6) All piping and pressure/vacuum protection systems (including valves) are to be provided with heat tracing arrangements so as to keep them readily operable.

(7) The maximum temperature of heating media within the cargo area is to be controlled within safe and controllable limits, taking into account the auto ignition temperature of the cargoes being carried.

(8) Equipment used for the environmental control of the cargo spaces, inter-barrier spaces and other spaces are to be designed to maintain a dew point below the lesser of the design service temperature or -30℃.

(9) Spaces required to be ventilated before entering are to be equipped with suitable means of pre-heating the ventilation systems to provide for their proper functioning at the design service temperature.

(10) If the cargo manifold and cargo vapor areas and associated valves are enclosed from the weather, the enclosures are to be arranged in such a way as to provide for sufficient ventilation of the space during cargo loading and unloading. Where mechanical ventilation is provided, the number of air changes is to be at least 30 per hour based on the gross volume of the space. In addition, gas detectors are to be provided.

(11) The vent mast head is to be designed to prevent blockage by ice accretion. Drip pans for the purpose of collecting moisture in the vent mast are to be provided. Drip pans with associated drain pipes inside the vent mast head and foot are to be provided with heat tracing.

(12) A steam-operated vapor heater for the purpose of preventing vapor descending to the deck is to be installed in the vapor line before the vent riser used for controlled venting.

(13) Insulation of the boil-off gas piping is required in way of areas exposed or subject to the design service temperature.

(14) The air intakes and exhaust louvres for cargo control rooms, cargo pump rooms, compressor rooms and motor rooms (where fitted) are to be provided with anti-icing protection by de-icing measures or heating arrangements.
(15) De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.
(16) The piping system providing water curtain for the cargo loading and unloading area is to be provided with anti-freezing arrangements. Seawater for the water curtain may be preheated to avoid excessive ice accretion at the side shell plating.
23.10.4.6 A water spray system installed on exposed deck is to be equipped with heating arrangements for anti-freezing protection, and to be dried immediately after use.
23.10.4.7 Dry chemical powder systems are to be so arranged as to prevent clogging of the nozzles, and being capable of releasing the medium at the design service temperature.
23.10.4.8 The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.
23.10.4.9 Monitoring systems are to comply with the following requirements:
(1) Heat tracing systems are to be provided with the temperature monitoring function so that any system failure or temperature exceeding limits will result in an alarm at the manned control station.
(2) The following instruments and equipment, when exposed to the low air temperature environments, are to be provided with heat tracing systems:

① level indicators for cargo tanks;
② overflow control;
③ pressure gauges;
④ temperature-indicating devices;
⑤ instrumentation for gas detection systems.

23.10.5 Offshore supply vessel

23.10.5.1 Offshore supply vessels applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.5.2 Piping systems arranged on exposed decks are to comply with the following additional requirements:
(1) Drilling muds and other specialized bulk cargoes carried by offshore support vessels may be particularly susceptible to freezing and may flow less freely in low air temperature environments. This fact is to be taken into account in the design. Valves and control stations are to be suitably located so as to be protected from cold and ice/snow accretion, as practicable.
(2) Where the transfer of fuel, drilling muds and other specialized bulk cargoes to drill ships at sea is anticipated, all equipment associated with the transfer such as, hoses, valves, fittings, etc. are to be suitable for operation under the minimum anticipated temperature.
23.10.5.3 For vessels with a rescue zone, suitable arrangements are to be provided for anti-icing protection:
(1) on a cross-deck area between the rescue zones port and starboard;
(2) the railings and handrails in the rescue zone; and
(3) routes to the accommodation/treatment areas.

23.10.6 Other ship types

23.10.6.1 Other ship types applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.6.2 For container ships, the exposed cargo securing arrangements are to be prevented from freezing, the material of which are to be suitable for the design service temperature, and are to be provided with grease suitable for use in low air temperature environments and with de-icing measures.
23.10.6.3 For container ships, where five layers or more of containers are stowed on exposed deck, the stowage positions for portable fire-extinguishing monitors are to be provided with anti-icing and anti-freezing protection, and the monitors are to be dried immediately after use.
23.10.6.4 For standby ships/rescue ships, the rescue facilities, if provided, are to be provided with anti-icing protection.

23.10.6.5 For standby ships/rescue ships, helicopter decks or hovering areas, if provided, are to be provided with de-icing measures, to ensure normal operation of the deck/area at the design environmental conditions for a period of one hour.
23.10.6.6 External fire-extinguishing appliances of fire-fighting ships are to be provided with anti-icing and anti-freezing protection.

Section 11 ANTI-ICING AND DE-ICING MEASURES

23.11.1 Application

23.11.1.1 This Section applies for ships operating occasionally in low air temperature environments and also for ships operating in areas and during periods where more severe ice and snow accretion are likely to occur but not in low air temperature environments.
23.11.1.2 The anti-icing and/or de-icing measures complying with this Section are to be taken by the above-mentioned ships.

23.11.2 Class notation

23.11.2.1 Ships complying with the provisions of this Section are to be assigned with the following notation:
(1) winterization de-icing notation: DE-ICE.

23.11.3 Plans and documents

23.11.3.1 The following plans and documents are to be submitted for approval:
(1) Arrangement of anti-icing and de-icing equipment, indicating heating capacity;
(2) Single line diagram of heating cables, if provided;
(3) Piping diagram of steam or heating fluids, if provided;
(4) Stability calculations in which ice accretion is considered;
(5) Anti-icing and de-icing procedures manual.
Items (4) and (5) above are always to be kept on board ships.

23.11.4 Main methods for anti-icing/de-icing

23.11.4.1 Main methods for anti-icing are:
(1) heating by steam, hot fluids or heating cables;
(2) using permanent or removable protective covers.
23.11.4.2 Main methods for de-icing are:
(1) flushing by hot water or steam;
(2) de-icing by mechanical means manually;
(3) using hot air or chemical substances.

23.11.5 Technical requirements

23.11.5.1 The anti-icing and de-icing arrangements of ships are to comply with the requirements given in Table 23.11.5.1.

Anti-icing and De-icing Arrangements **Table 23.11.5.1**

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Ship arrangements		
Tanks	The ship is to have an appropriate arrangement to prevent the surface of ballast tanks, fresh water tanks and other relevant tanks from freezing over considering the minimum anticipated temperature.	23.3.3.1
Superstructures and decks		
Bridge windows	Bridge windows are to be fitted with heating and cleaning systems and are to function under the minimum anticipated temperature. Where the water flushing system is fitted, measures are to be taken to prevent pipelines and fittings from freezing and thus becoming inoperable.	23.3.4.2
Bridge doors	Navigation bridge doors and the adjacent deck areas are to be so arranged as to prevent ice and snow accretion.	23.3.4.3
Master's cabin windows	At least one of the Master's cabin windows is to have a heating arrangement for a view over the cargo deck where necessary.	23.3.4.5
Exterior stairs and railings	Exterior stairs and railings not forming the escape routes are to be provided with anti-icing or de-icing protection.	23.3.4.7

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Helicopter decks or hovering areas	Helicopter decks or hovering areas, if provided, are to be provided with de-icing measures.	23.3.5.1
Stability		
Means for removing ice	Equipped with such means for removing ice; for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.	23.4.1.2(2)
Ice accretion monitoring	Monitored for ice accretion during operation and appropriate measures are to be taken to ensure that ice accretion allowance does not exceed the value specified in the Stability Manuel.	23.4.1.2(3)
Watertight and weathertight integrity		
Ramp doors and side doors	Ramp doors and side doors are to be provided with means to remove ice accretion around hatches and doors.	23.5.2.2
Freeing ports	Freeing ports are to be fitted with anti-icing protection.	23.5.3.2(1)
Scuppers and discharges	For decks, passageways and muster areas that are required to be kept ice-free, the scuppers and discharges in such spaces are to be provided with anti-freezing protection.	23.5.3.3
Main and auxiliary machinery		
Combustion air intakes	The combustion air intakes are to be located on both sides of the ship and so arranged as to prevent the recirculation of engine exhaust gases into the combustion air intakes, ice/snow accretion and blockage of the duct.	23.6.2.2(4)
Piping		
Exposed valves	Exposed valves are to prevent the accumulation of snow and spray ice.	23.6.4.2(2)
Piping components located in exposed or low temperature spaces	Piping components located in exposed or low temperature spaces, such as valve control units, manifolds, vents, gasket seals, and thermal instruments such as indicators, sensors and other fittings, are to be provided with anti-icing, anti-freezing protection or other means to provide for continued functionality.	23.6.4.2(3)
Exposed air vent pipe heads	Exposed air vent pipe heads are to be provided with anti-icing measures against blockage, such as electric heat tracing or protective cover; where protective covers are provided against icing, the covers are not to interfere with the free flow of air through the vent openings.	23.6.4.3(2)
Sea chests	At least one sea chest is arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.	23.6.4.8(1)
Exposed control stand valves	Exposed control stand valves for hydraulic oil lines used for remote control are to be provided with heating arrangements for anti-freezing protection of the mechanism.	23.6.4.10(3)
Electrical installations		
Generators and electric motors installed on exposed decks and in low temperature spaces	Generators and electric motors installed on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.	23.6.5.3
Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces	Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.	23.6.5.4
Illumination lights and navigation lights installed on exposed decks	If illumination lights and navigation lights installed on exposed decks cannot generate sufficient heat to keep the light fixture ice-free, they are to be readily accessible and suitable for manual de-icing, or heating arrangements are to be provided.	23.6.5.7
Deck machinery		
Exposed control panels of deck machinery	Exposed control panels of deck machinery are to be provided with protective covers or heating arrangements for anti-freezing protection.	23.6.3.1
Cab windows of cranes	Cab windows are to be provided with heating arrangements to prevent icing.	23.6.3.3
Anchor windlass and its control	The anchor windlass and exposed windlass controls are to be provided with appropriate covers or heating arrangements for anti-icing protection. Alternatively, they are to be arranged in enclosed or semi-enclosed deck areas.	23.6.3.5
Anchor chains	Anchor chains are to be capable of being de-iced manually.	23.6.3.5
Hawse pipes	The hawse pipes are to be provided anti-icing protection or de-icing protection by steam or hot water.	23.6.3.6

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Hawse pipe wash lines	Hawse pipe wash lines are to be provided with continuous circulation or heating arrangements for anti-freezing protection of water in the pipes.	23.6.3.7
Mooring winches	Mooring winches are to be provided with suitable covers or heating arrangements for anti-icing protection. De-icing measures are to be arranged in the vicinity of mooring winches.	23.6.3.8
Fire fighting		
Isolating valves	The isolating valves in exposed locations are to be provided with anti-icing protection and located in areas where it is easily accessible.	23.7.1.4
Hydrants	Hydrants are to be provided with anti-icing and anti-freezing protection. The stowage positions for fire hoses and nozzles are to be provided with anti-icing and anti-freezing protection, the hoses and nozzles are to be dried immediately after use.	23.7.1.6
Portable extinguishers	The storage facilities for portable extinguishers are to be provided with anti-icing protection and readily accessible.	23.7.1.7
Sea chests of emergency fire pumps	Sea chests of emergency fire pumps are to be provided with means for heating, insulation or low pressure steam connection to prevent the blockage by floating ice.	23.7.2.3
Emergency routes	Essential emergency routes, such as escape routes, muster areas, lifeboat embarkation areas, are to be provided with anti-icing protection. Where exposed decks of the ship have no anti-icing requirements, de-icing tools to remove ice and snow accretion are to be provided to ensure the safety of persons onboard. Gangways and ramps are to be provided with de-icing arrangements.	23.7.4.1
Overhead structures	Overhead structures are to be provided with de-icing or other arrangements to prevent injuries to persons or damages to essential safety equipment/structures by fallen ice.	23.7.4.2
Escape routes	Escape routes are to be provided with anti-icing protection to ensure that the escape routes are ice-free or providing a minimum ice-free width of 700 mm, enabling the use of at least one railing. Railings that are important as hand-holds (stairs, escape ways) are to have anti-icing protection. Railings that function only as barriers, but are not intended as handholds, may be provided with de-icing arrangements only.	23.7.4.3
Exits forming escape routes	Exits forming escape routes are to be provided with anti-icing and de-icing measures.	23.7.4.6
Life-saving appliances		
Life-buoys	The bridge and exposed deck life-buoys are to be provided anti-icing protection and be arranged such that it is immediately deployable by the crew.	23.8.1.5
Release mechanism of lifeboats	The release mechanism of lifeboats is to be provided with heating or other arrangements to ensure safe release.	23.8.2.9
Vicinity of lifeboats	Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.	23.8.2.10
Launching appliances of survival craft and rescue boats	Electric motors, winches and automatic release hooks of survival craft and rescue boats are to have moveable covers.	23.8.5.2
Launching appliances of survival craft and rescue boats	Other members of launching appliances, such as winches, sheaves, winch brakes, etc. are to be provided with heating or other arrangements to ensure safe launching of survival craft and rescue boats.	23.8.5.4
Embarkation ladders	The stowage positions for embarkation ladders are to be provided with covers or heating arrangements to prevent ice accretion.	23.8.5.5
Navigational equipment		
Antennae	Arrangements are to be made to prevent damage to antennae due to accumulation of ice and snow except for whip type antennae. Antennae may be heated or placed in heated domes, or in a place easily accessible for manual de-icing.	23.9.1.2
Searchlight housing	Searchlight housing is to use heated glass or be provided with covers to prevent accumulation of ice and snow. The rotation mechanism is to be provided with anti-icing protection.	23.9.2.1
Magnetic compasses	Magnetic compasses installed on exposed decks are to be provided with protective covers.	23.9.2.2

23.11.5.2 Anti-icing and de-icing arrangements specific to ship types are also to comply with the requirements given in Table 23.11.5.2.

Anti-icing and De-icing Arrangements Specific to Ship Types **Table 23.11.5.2**

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Oil tanker/Chemical tanker		
Emergency towing arrangements	The emergency towing arrangements are to be arranged with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.	23.10.3.3
Cargo piping	① For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance. ② The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.	23.10.3.4(1) 23.10.3.4(2)
Inert gas systems and related equipment	① Means for the deck water seal are to be provided to ensure the added fluid to be free from freezing. Proper application of antifreeze or provision of heating arrangements may be used. ② The pressure/vacuum breakers are to be suitable for the minimum anticipated temperature. Proper application of antifreeze or provision of heating arrangements may be used. ③ Equipment requiring de-icing maintenance are to be grouped together as far as practicable and readily accessible.	23.10.3.4(4)② 23.10.3.4(4)⑤ 23.10.3.4(4)⑦
Pressure/vacuum valves	Pressure/vacuum valves are to be provided with suitable anti-icing protection and de-icing measures so as to keep the valves readily operable.	23.10.3.4(5)
Areas designated for control of cargo loading and unloading	De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.	23.10.3.4(6)
Safe access	The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.	23.10.3.5
Liquefied gas carriers		
Cargo containment system or any cover for the containment system	For cargo containment system or any cover for the containment system exposed outside the hull, special consideration is to be given to ice and snow loads on the system or the cover.	23.10.4.2
Emergency towing arrangements	The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.	23.10.4.4
Cargo piping	① For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance. ② The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.	23.10.4.5(1) 23.10.4.5(2)
Safety relief valves and other valves	Exposed cargo related safety relief valves and other valves are to be provided with de-icing and heat tracing arrangements.	23.10.4.5(4)
Emergency shutdown valves	Emergency shutdown (ESD) valves are to be provided with anti-icing protection.	23.10.4.5(5)
Vent masts	The vent mast head is to be designed to prevent blockage by ice accretion.	23.10.4.5(11)
Air intakes and exhaust louvres	The air intakes and exhaust louvres for cargo control rooms, cargo pump rooms, compressor rooms and motor rooms (where fitted) are to be provided with anti-icing protection by de-icing measures.	23.10.4.5(14)
Areas designated for control of cargo loading and unloading	De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.	23.10.4.5(15)
Water spray systems	A water spray system installed on exposed deck is to be equipped with heating arrangements for anti-freezing protection, and to be dried immediately after use.	23.10.4.6
Safe access	The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.	23.10.4.8
Offshore supply vessels		

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Piping for drilling muds and other specialized bulk cargoes	The valves and control stations of piping for drilling muds and other specialized bulk cargoes are to be suitably located so as to be protected from cold and ice/snow accretion, as practicable.	23.10.5.2(1)
Rescue zones	For vessels with a rescue zone, suitable arrangements are to be provided for anti-freezing protection: (1) on a cross-deck area between the rescue zones port and starboard; (2) the railings and handrails in the rescue zone; and (3) routes to the accommodation/treatment areas.	23.10.5.3
Container ships		
Cargo securing arrangements of container ships	For container ships, the exposed cargo securing arrangements are to be prevented from freezing, and are to be provided with grease suitable for use in low air temperature environments and with de-icing measures.	23.10.6.2
Portable fire-extinguishing monitors of container ships	For container ships, where five layers or more of containers are stowed on exposed deck, the stowage positions for portable fire-extinguishing monitors are to be provided with anti-icing and anti-freezing protection, and the monitors are to be dried immediately after use.	23.10.6.3
Standby ships and rescue ships		
Rescue facilities	For standby ships and rescue ships, the rescue facilities, if provided, are to be provided with anti-icing protection.	23.10.6.4
Helicopter decks or hovering areas	For standby ships and rescue ships, helicopter decks or hovering areas, if provided, are to be provided with de-icing measures, to ensure normal operation of the deck/area at the design environmental conditions for a period of one hour.	23.10.6.5
Fire-fighting ships		
External fire-extinguishing appliances of fire-fighting ships	External fire-extinguishing appliances of fire-fighting ships are to be provided with anti-icing and anti-freezing protection.	23.10.6.6

Section 12 SURVEY REQUIREMENTS FOR ANTI-COLD CLIMATE NOTATIONS

23.12.1 General requirements

23.12.1.1 This Section applies to plan approval and survey of ships to be assigned with Anti-Cold Climate notations in accordance with the requirements of this Chapter, to verify anti-cold climate measures are suitable for ship's operation in anticipated low air temperature environments.

23.12.1.2 In plan approval, installation and testing according to the requirements of this Section, the requirements of the flag State Administration and/or the Administration of the ship's intended operational areas, and of the relevant international conventions are to be taken into account for anti-cold climate measures; if applicable, it is to be ensured that they are not contradictory to the statutory requirements and to be confirmed that anti-cold climate measures will not impair or weaken the normal operation of the relevant equipment and systems.

23.12.1.3 For equipment, systems and components exposed to low air temperature environments, the design service temperature is to be specified. All relevant purchase orders and plans are to indicate the temperature to ensure it complies with the appropriate approval and the requirements of the impact strength test at low temperature. Such equipment, systems and components are to be confirmed that there is the evidence of the design service temperature performance, which may include the marine product certificate issued by ISC, or statement of the manufacturer, or statement of experience at similar ambient temperature.

23.12.1.4 If the design service temperature of structural materials of the ship (DST_1) is lower than the design service temperature of equipment and system anti-cold climate measures (DST_2), H(DST_1) notation may be assigned individually. In this case, the polar service temperature (PST) of the polar ships is to be taken as DST_2.

23.12.2 Initial survey

23.12.2.1 In the process of plan approval, a design evaluation of anti-cold climate measures is to be carried out based on plans and documents submitted according to 23.1.4 of this Chapter, to confirm their

compliance with the rules requirements and their adequacy and suitability being verified, but not to confirm technical details of the specific anti-cold climate measures.

23.12.2.2 The hull and machinery arrangements are to be surveyed to confirm their compliance with the rules requirements and approved plans. The installation and testing of structures, equipment, systems and outfittings according to the agreed plan are to be conducted to the satisfaction of the Surveyor, of which the start-up and operation are to be verified, but their performance at the design service temperature are not necessarily confirmed.

23.12.3 Survey after construction

23.12.3.1 Survey to maintain class notations is to be carried out within 3 months before or after the anniversary date of assigning the Anti-Cold Climate notations except for the H(DST) notation.

23.12.3.2 During an annual survey, the Surveyor is to confirm that the arrangements and equipment comply with the rules and to verify as far as practicable the functions of the installed equipment and related controls and alarm systems according to the anti-cold climate measures listed in 23.1.4.2 and/or 23.11.3. The survey is to include but not limited to the following applicable items:

(1) Hull:

① anti-freezing arrangements for tanks;

② anti-icing/de-icing arrangements for passageways and openings;

③ heating arrangements for essential spaces;

④ heating and cleaning systems for bridge windows;

⑤ anti-cold climate measures for life-saving appliances and fire-fighting systems.

(2) Machinery, equipment and systems:

① For all ships:

a. pre -heating and introduction of combustion air for internal combustion engines and other prime movers;

b. anti-cold climate measures for deck machinery;

c. de-icing and anti-freezing arrangements for exposed piping;

d. anti-cold climate measures for navigational equipment;

e. emergency heating system for specified spaces, and tests are to be carried out where necessary.

② For bulk carriers and ore carriers:

a. anti-freezing arrangements connecting the upper and lower wing tanks.

③ For oil tankers and chemical tankers:

a. anti-freezing arrangements for the related equipment of the inert gas system, if fitted;

b. inspecting heat-tracing of additional fire-fighting and safety systems;

④ For liquefied gas carriers:

a. ventilation and gas detectors of enclosed cargo areas, if fitted;

b. inspecting heat-tracing of additional fire-fighting and safety systems provided according to ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk.

⑤ For offshore supply vessels:

a. for vessels with a rescue zone, anti-icing arrangements of the following positions are to be inspected:

(a) on a cross-deck area between the rescue zones port and starboard;

(b) the railings and handrails in the rescue zone; and

(c) routes to the accommodation/treatment areas.

23.12.4 Products inspection

23.12.4.1 Products for ships assigned with the Anti-Cold Climate notations are to specify the conditions for use in the relevant plans, purchase documents, survey notices or applications, including installation positions, minimum ambient temperature, anti-cold climate measures, etc.

23.12.4.2 Exposed equipment and systems are to consider the low temperature impacts in the following aspects, as appropriate, to verify their functionality at the design service temperature:

(1) materials and welding of structures and components, including low temperature resistant brittle materials and low temperature welding procedures;

(2) seal materials, with low temperature resistant performance;

(3) lubricating medium, using grease with low temperature performance;

(4) warm-keeping measures, including heat tracing (power), cover;

(5) de-icing methods, including limitations and requirements of de-icing methods;

(6) moving components, low temperature impacts;

(7) working medium, using hydraulic oil with low temperature performance;
(8) drives: hydraulic motor, electric motor, hydraulic pump, etc. involving the measures above;
(9) control box: low temperature impacts.

23.12.4.3 Where necessary, the marine product certificate is to indicate the design service temperature.

CHAPTER 24 ADDITIONAL REQUIREMENTS FOR STAND-BY SHIPS AND RESCUE SHIPS

Section 1 GENERAL PROVISIONS

24.1.1 Application

24.1.1.1 Unless expressly provided otherwise, this Chapter applies to stand-by ships and rescue ships.

24.1.1.2 Stand-by ships and rescue ships are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of ISC Rules for Materials and Welding and of the flag State Administration, if any.

24.1.2 Notation

24.1.2.1 Stand-by ships complying with the provisions of this Chapter may be assigned the notation: Stand-by Ship.

24.1.2.2 Rescue ships complying with the provisions of this Chapter may be assigned the notation: Rescue Ship.

24.1.3 Definitions

24.1.3.1 Stand-by ship means ships providing safety stand-by and conventional rescue for offshore installations or ships in operation, capable of receiving personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or of rescuing personnel from sea.

24.1.3.2 Rescue ship means ships engaged in rescue operations at sea for ships and crew in distress.

24.1.3.3 Survivors mean personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or rescued from sea.

24.1.4 Plans and documents

24.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to ISC for approval. For special structures and arrangements, the scope of plans and documents to be submitted for approval may be expanded if deemed necessary by ISC:

(1) Arrangement of safety and rescue equipment;

(2) System diagram and arrangement of searchlights;

(3) System diagram of aviation frequency two-way VHF radiotelephone apparatus.

24.1.4.2 The following plans and documents are to be submitted to ISC site surveyors:

(1) Operation manual, in working language, available onboard for the crew. The operation manual is to include:

① safety stand-by and rescue information and training details provided by the ship owner or operator;

② maintenance and operation of safety and rescue equipment, including the arrangement and information on the use of radio apparatus onboard provided as required;

③ safety and rescue procedures, to guide the evacuation of personnel from offshore engineering installations and offshore structures or from other ships, or the rescue of personnel from sea;

④ operation details of safety and rescue;

⑤ dynamic capability analysis (ship's mooring, heading keeping capability, speed, etc., under the specified sea conditions).

Section 2 CONSTRUCTION AND ARRANGEMENT

24.2.1 Superstructures and deckhouses

24.2.1.1 The structure is to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.2 Windows are to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.3 Navigation bridge

(1) The navigation bridge is to be so arranged that there is an unobstructed view all around. Clear view at the navigation bridge is to be ensured during safe rescue operations.

(2) Windows are to be installed from the outside except for those on the aft bulkhead.

24.2.2 Rescue zone

24.2.2.1 A rescue zone with a length of not less than 5 m is to be established and extended as far as possible on each side of the ship.

24.2.2.2 The rescue zone is to be located well clear of the propellers and as close to midships as practicable, with a clear deck area portside to starboard to permit the boarding of survivors and to carry on rescue operations.

24.2.2.3 Handrails in the rescue zone are to be provided with doors or chains which are readily openable, or removable stanchions are to be used. Bulwarks in the rescue zone are to be provided with doors, openings or other means of embarkation. Such means of embarkation are to be arranged to facilitate the hanging and use of boarding nets.

24.2.2.4 The rescue zone is to be provided with boarding nets fitted with lifelines.

24.2.2.5 The rescue zone is to be free of hull fittings and projections and overboard discharges which would impede rescue operations.

24.2.2.6 The rescue zone is to be provided with lighting required by 24.4.5.

24.2.2.7 The rescue zone is to be marked so as to be readily identified from seaward.

Section 3 ACCOMMODATION SPACES FOR SURVIVORS

24.3.1 Provision requirements for the spaces

24.3.1.1 General requirements

(1) Spaces provided for shelter of the survivors are to be enclosed from the weather and provided with heating, lighting and ventilation facilities.

(2) In emergency, the survivors may be lodged in the accommodation spaces other than the following spaces: sanitary area, galley, the master's cabin, radio room, navigation bridge and main passages that are to be kept unblocked.

(3) The dimension of the shelter spaces for the survivors is to be indicated on the general arrangement plan.

24.3.1.2 The area of the shelters is to be determined as 0.75 m^2 for every assigned survivors, including free spaces and floors for movable furniture, fixed seating and fixed beds; other fixed furniture, toilets and bathrooms are not to be included.

24.3.1.3 Sanitary facilities

(1) Dedicated sanitary facilities are to be provided for the survivors. One set of fixtures comprising a toilet, a washing basin and shower, is to be provided for every 50 survivors.

(2) Fresh water tanks and potable water tanks of sufficient quantity are to be provided for the survivors onboard.

24.3.1.4 Treatment area

(1) The treatment area is to be readily accessible for the survivors from the rescue zone and is to be effectively isolated from the crew's accommodation area.

(2) Given the situation when the survivors are transferred to the helicopter winching area, the arrangement of the treatment area is to make transfer passage easily accessible and unobstructed.

(3) Corridors and doors leading to the rescue zone are to be sufficient in width to allow the passage of stretchers transferring survivors.

Section 4 RESCUE AND SAFETY EQUIPMENT

24.4.1 Rescue boats

24.4.1.1 A rescue boat is to be provided on a stand-by ship.

24.4.1.2 A readily available fast rescue boat is to be provided on a rescue ship.

(1) The rescue boat and its launching appliances are to comply with the requirements of Chapters V and VI of the International Life-saving Appliance (LSA) Code.

(2) Where davits for rescue boats have to rely on electricity for operation, they are to be power supplied by emergency switchboard.

24.4.2 Rescue nets

24.4.2.1 Rescue nets are not to be less than 5 m in width with the center of gravity at bottom.

24.4.2.2 The length of the rescue nets is to extend at least 1 m below the waterline at lightest draught.

24.4.3 Searchlights

24.4.3.1 Two searchlights capable of rotating 360° horizontally are to be provided. The searchlights are remotely controllable at the navigation bridge.

24.4.3.2 The searchlights are to provide at least 50 lux illumination at a distance of 250 m.

24.4.4 Water spray fire extinguishing systems

24.4.4.1 The water spray fire extinguishing system is to be provided on a rescue ship to protect the rescue operation area on the open deck against the heat and fire in the boundary of the rescue zone.

24.4.4.2 The nozzles of the water spray fire extinguishing system are to be arranged to give an even distribution of waterspray over the whole rescue operation area on the open deck.

24.4.4.3 The water spray fire extinguishing system is to ensure even distribution of water spray in the rescue operation area.

24.4.4.4 The water spray fire extinguishing system is to have a capacity of at least 5 *l*/min per m^2 of the protected area which is internally insulated to A-60 class and at least 10 *l*/min per m^2 of other protected areas.

24.4.4.5 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area of the rescue zone. Where the main fire pumps are used for this purpose, they are to be capable of operating this system, the water monitors and the hose stations simultaneously at the required pressure. A connection with a shut-off valve is to be fitted between the piping system for the water monitors and the supply line for the water spray fire extinguishing system.

24.4.4.6 Means are to be taken to ensure that necessary visibility from the navigation bridge and the remote-control station can be maintained during the water spray operations.

24.4.5 Deck illumination

24.4.5.1 Main lighting and emergency lighting are to be provided in the following areas:

(1) rescue boat stowage locations, launching appliances, reception and rescue areas;

(2) to provide floodlighting of the sea in way of the rescue zone and rescue boat launch and recovery area;

(3) the helicopter winching deck area and access routes leading to and from the reception area.

24.4.6 Treatment facilities

24.4.6.1 Treatment facilities, including stretchers, blankets or coverings, bandages and dressing, splints, thermal insulation blankets and insulation materials, etc. are to be provided.

24.4.6.2 The treatment facilities are to be readily available.

24.4.6.3 The treatment facilities are to be appropriately wrapped, labeled, stored and marked.

24.4.7 Towing

24.4.7.1 Means to tow rescue boats, lifeboats or liferafts are to be provided.

24.4.8 Other life-saving appliances

24.4.8.1 The relevant life-saving appliances are to be provided according to Table 24.4.8.1.

Other Life-Saving Appliances **Table 24.4.8.1**

Appliance	Quantity
Fall protection equipment (e.g. safety harness and safety line with hook)	3
Throw lines	4
Diver ladders	2
Lifejackets	Assigned number of survivors
Long handle hooks	2
Lifebuoys with self-igniting lights and ropes (not less than 30 m in length)	4

24.4.9 Helicopter winching deck area

24.4.9.1 Helicopter winching deck area is to be provided. The area is to be unobstructed and well-illuminated.

Section 5 NAVIGATION AND COMMUNICATION EQUIPMENT

24. 5.1 Navigation equipment

24.5.1.1 Regardless of its dimension, shipborne navigation equipment required to be provided for cargo ships of 500 gross tonnage and above according to the Administration is to be provided.

24.5.2 Radiocommunications

24.5.2.1 One two-way VHF radiotelephone using aviation frequency (121.5 MHz and 123.1 MHz) is to be provided, in addition to the radio equipment required by the Administration.

CHAPTER 25 ADDITIONAL REQUIREMENTS FOR DIVING SUPPORT VESSELS

Section 1 GENERAL PROVISIONS

25.1.1 Application

25.1.1.1 This Chapter applies to vessels supporting diving operations or unmanned remotely operated vehicles operations.

25.1.1.2 Diving support vessels are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of ISC Rules for Materials and Welding and of the flag State Administration, if any.

25.1.2 Notations

25.1.2.1 The following notations may be assigned to vessels complying with the requirements of this Chapter[①]:

Diving Support Vessel[②] is assigned to vessels permanently supporting diving system and complying with the relevant requirements of this Chapter.

DSV-Air is assigned to vessels supporting conventional air diving systems and complying with the relevant requirements of this Chapter.

DSV-Sat is assigned to vessels supporting saturation diving systems and complying with the relevant requirements of this Chapter.

Types of Diving **Table 25.1.2.1**

	Type of diving	
Parameter	DSV-Air	DSV-Sat
Designed diving depth	≤58 MSW	≤457 MSW
Diving duration	≤8 hours	No restriction
Breathing air medium	compressed air	Heliox or equivalent
MSW = Metres Sea Water		

25.1.2.2 Vessels complying with the requirements of Section 6 of this Chapter may be assigned the notation ROVS.

25.1.3 Definitions

25.1.3.1 Diving support vessels are mother vessels supporting diving operations or submersible system operations.

25.1.4 Plans and documents

25.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to ISC for approval. For special structures and arrangements, the scope of plans and documents to be submitted for approval may be expanded if deemed necessary by ISC:

(1) Arrangement of the diving system;

(2) Details of hull supporting structure for submersible and its handling system;

(3) Electrical loading evaluation of diving system operation conditions during the operation of the diving system;

(4) Power system diagram and electrical equipment arrangement of the diving system;

(5) Piping schematics for the diving support vessel's piping systems supplying diving systems;

(6) Arrangement and details of communication systems between the diving support vessel and diving systems.

25.1.4.2 The following plans and documents are to be submitted to ISC for information:

(1) Design details of foundation for submersible and its handling system;

(2) Calculations of supporting structure for submersible and its handling system.

---

① DSV-Air, DSV-Sat may be assigned together with the notation Diving Support Vessel or separately as special performance notations.

② The DSV-Sat notation must be obtained for granting the Diving Support Vessel notation

25.1.4.3 The following plans and documents are to be submitted to ISC site surveyors:
(1) Operation manual.

Section 2 SEA KEEPING OF VESSEL'S POSITION

25.2.1 General requirements

25.2.1.1 During the operation of the diving system, the diving support vessel is to be capable of withstanding wind and wave in order to maintain its position at sea.

25.2.1.2 The means to maintain position may be a mooring system with anchors or a dynamic positioning system.

25.2.2 Dynamic positioning systems

25.2.2.1 Where the diving support vessel uses the dynamic positioning system to maintain its position, such dynamic positioning system is to comply with the relevant provisions for DP-2 or DP-3 in Chapter 11 of this PART.

Section 3 ARRANGEMENT OF DIVING SYSTEMS

25.3.1 Installation location of diving systems

25.3.1.1 The diving system is to be installed in the non-hazardous area of the diving support vessel (IEC 60079-1). Special consideration is to be given as appropriate if the system is installed in the hazardous area.

25.3.1.2 Diving systems and breathing gas storage facilities are not to be installed in machinery spaces, except for equipment not used for operating the diving system.

25.3.1.3 Diving systems are not to be installed in the vicinity of exhausts/ventilation outlets from machinery spaces and galleys.

25.3.1.4 The diving system is to be located so that the diving operations are not affected by propellers, thrusters or anchors of the diving support vessel.

25.3.1.5 The diving system is to be so arranged that diving operations are conducted as far away as practicable from the vessel's overboard discharge outlets/suction inlets.

25.3.1.6 Where an impressed current cathodic protection system is fitted, the system is to be switched off during the diving operations.

25.3.1.7 Where pressure vessels serving divers are fitted, such as the deck pressurized tank, it is recommended that the pressure vessels are arranged longitudinally along the diving support vessel so as to reduce the impact of rolling on divers.

25.3.1.8 Diving systems are to be installed in spaces or locations that are adequately ventilated and provided with suitable lighting on the diving support vessel.

25.3.1.9 Where any part of the diving system is located on the open deck, reasonable protection is to be provided so as to prevent damages caused by wave, ice or other activities onboard.

25.3.1.10 In order to minimize deflections and to obtain satisfactory transfer of heavy loads through the deck foundations, it is recommended that diving systems be installed in-line with the supporting deck structure.

25.3.2 Storage room for breathing gas cylinders of the diving system

25.3.2.1 Breathing gas cylinders for diving systems are to be stored on the open deck or in well ventilated enclosed spaces, and away from flammable substances and sources of ignition.

25.3.2.2 Where breathing gas cylinders are stored on the open deck area, weathertight shelters against wave and heat radiation and effective protection against mechanical damages are to be provided for the cylinders.

25.3.2.3 The boundaries between the enclosed spaces storing breathing gas cylinders and other enclosed spaces are to be gastight. The doors of the enclosed spaces are to open outward.

25.3.2.4 The storage area or space for breathing gas cylinders is to be provided with appropriate draining arrangements.

25.3.2.5 The outlets of relief valves or bursting discs are to be piped-outside the enclosed spaces to the open deck and away from sources of ignition.

25.3.2.6 The enclosed spaces storing breathing gas cylinders are to be provided with an independent ventilation system, the outlets of which are in safe areas. The ventilation capacity of the forced ventilation

system is to be such as to provide for at least eight air changes per hour, based on the gross volume of the enclosed spaces.
25.3.2.7 The air of the ventilation system is to be drawn from safe areas.
25.3.2.8 The fans of the ventilation system are to be of non-sparking construction.
25.3.2.9 Breathing gas mixtures containing more than 25% oxygen by volume are to be treated and handled as pure oxygen.
25.3.2.10 Pure oxygen breathing gas cylinders are to be stored on the open deck, but not to be stored in the spaces or areas below the deck.
25.3.2.11 When breathing gas mixtures containing less than 25% oxygen by volume are stored in enclosed spaces, the following requirements are to be complied with:
(1) at least two oxygen analyzers fitted with audible and visual alarms are to be provided, one of which is used to monitor the upper levels of the enclosed spaces and the other of which is used to monitor the lower levels of the enclosed spaces;
(2) the enclosed spaces for storage of the breathing gas cylinders are to be kept clean, i.e. free of grease or other debris.
25.3.2.12 Where the diving support vessel is also used for fire-fighting operations, means are to be provided to protect the oxygen cylinders from heat that may radiate from the fire that is being extinguished.

25.3.3 Diving system control station

25.3.3.1 Where the diving support vessel is permanently provided with the diving system, the diving system control station is to comply with the requirements of this Chapter.
25.3.3.2 The diving system control station is to be securely fastened at a location close to and in sight of the diving location.
25.3.3.3 The position of the diving system control station is to allow the operations control personnel an overview of the diving system, including all activities related to the submersible operations.
25.3.3.4 The diving system control station is not to be located in the hazardous area.
25.3.3.5 When selecting the location of the diving system control station, ship's motion or support structure vibrations are to be considered.
25.3.3.6 A direct two-way direct communication systems are to be provided between the diving system control station and the following spaces or persons as applicable:
(1) diver in the water;
(2) diving bell;
(3) each chamber of the deck decompression chambers;
(4) operating space of the handling system and the emergency control station;
(5) dynamic positioning control station;
(6) navigation bridge.
25.3.3.7 Emergency communication means are to be provided between the control station of a diving system and divers in its deck decompression chamber and diving bell.
25.3.3.8 Where more than one control station are provided onboard for the diving system, direct communication is to be provided between these stations.

25.3.4 Power supply and illumination of the diving system

25.3.4.1 Electrical installations essential to safe completion of the diving operations are to be supplied from the main and emergency power sources.
25.3.4.2 The main power source of the diving support vessel may be used to supply normal power to diving systems, provided that the main power source of the vessel has sufficient capacity simultaneously supply the vessel's electrical loads as well as the electrical loads of the diving systems. The main power source of the diving system can also be supplied by the dedicated self-contained power source.
25.3.4.3 In the event of failure of the main source of electrical power to the diving system, an independent emergency source of electrical power is to be available for the safe termination of the diving operation. The emergency power source can be dedicated self-contained power source (provided by the vessel or fitted on the submersible), or the emergency power source mentioned in 25.3.4.4.
25.3.4.4 The emergency generator of the diving support vessel can be used as the emergency power source mentioned in 25.3.4.3, provided that the emergency power generator has sufficient capacity to supply the emergency electrical loading of the diving support vessel and of the diving system simultaneously.
25.3.4.5 The power supply extent and duration of the emergency power source of the diving system are to comply with 10.2.1.9 and 10.2.1.10, Chapter 10 of ISC Rules for the Construction and Classification of Diving Systems and Submersibles.

25.3.4.6 The emergency power source of the diving system is to be installed outside the engine room of the diving support vessel and be as far apart as practicable from the main power generator.
25.3.4.7 Appropriate illumination is to be provided at the interface between the diving system and the diving support vessel. The critical handling area of the diving system is to be provided with illumination supplied by the main and emergency power source.

Section 4 STRUCTURAL REQUIREMENTS

25.4.1 Deck foundations, fastening arrangements and hull supporting structures
25.4.1.1 Deck foundations and fastening arrangements are to permit relative movement of manned pressure vessels and large gas storage cylinders due to internal pressure variations that may cause them to expand/contract.
25.4.1.2 For manned pressure vessels and large gas storage cylinders installed on the diving support vessel, the relevant requirements for the installation of independent tanks (independent pressure vessels) onboard may be referred to.
25.4.1.3 For the submersible and its handling system, the strength of the supporting structure is to be checked. For the calculation and modelling methods, the relevant requirements of Chapter 1, PART TWO of the Rules may be referred to, where: inertia force of the foundation and fastening arrangements of the submersible may be calculated according to Section 5, Chapter 1, PART TWO of the Rules; ② the design load of the handling system of the submersible is to comply with the requirements of Appendix B of ISC Rules for the Construction and Classification of Diving Systems and Submersibles.
25.4.1.4 The calculation stress of the hull supporting structure of the submersible is not to be greater than the permissible value in Table 3.7.4.12, Chapter 3, PART TWO of the Rules. The calculation stress of the hull supporting structure under the foundation of the handling system of the submersible is to satisfy the requirements in 3.10.7, Chapter 3 of ISC Rules for the Construction and Classification of Diving Systems and Submersibles.

25.4.2 Moon pools
25.4.2.1 Moon pools, where provided for diving operations are to meet the following requirements:
(1) Openings are to be a suitable distance from the deck edge, from cargo hatch covers, from superstructure breaks and from other area of structure discontinuity.
(2) The side structure of moon pools are to be designed for impact loads from diving equipment that may be guided through the moon pools.
(3) The plating thickness of the moon pool side structures is not to be inferior to the requirements for shell plating in Section 3, Chapter 2, PART TWO of the Rules.
(4) The corner radius of the moon pool opening is to comply with the requirements of 2.4.4, PART TWO of the Rules.
(5) Free edges of the moon pool opening are to be suitably rounded in order to protect diving system umbilicals from sharp edges.
(6) Means of protection are to be provided around the moon pool opening, such as guardrails, to prevent personnel from falling into the moon pool.

Section 5 FIRE-FIGHTING

25.5.1 Structural protection
25.5.1.1 Diving systems installed in enclosed spaces
(1) Enclosed spaces on diving support vessels housing diving systems are to be separated from adjacent spaces by means of A-60 class bulkheads or decks. All doors between these enclosed spaces and adjacent enclosed spaces are to be of the self-closing type. The enclosed spaces of the diving system are not to be connected to the machinery spaces of category A.
(2) Pipes and cables passing through the bulkheads and decks of the enclosed spaces are to be of A-60 class mechanical penetrations or electrical penetrations.
(3) The enclosed spaces of the diving system are to be provided with independent forced ventilation. The outlets of the ventilation system are to be in the safe areas. The ventilation capacity of the forced ventilation system is to be such as to provide for at least eight air changes per hour, based on the gross volume of the enclosed spaces.

25.5.1.2 Diving systems installed on the open deck

(1) The diving system may be installed on the open deck or similar structures directly adjacent to the machinery spaces of category A.

(2) Where the diving system is installed in areas directly adjacent to the machinery spaces of category A, the bulkheads and decks are to be of A-60 class division.

25.5.2 Fire-extinguishing systems and means of cooling

25.5.2.1 Diving systems installed in enclosed spaces

(1) Fixed fire extinguishing systems installed in enclosed spaces are to be:

① fixed pressure water spray fire-extinguishing systems suitable for machinery spaces of category A according to the requirements of the FSS Code; or

② fixed gas fire-extinguishing systems suitable for machinery spaces of category A according to the requirements of the FSS Code; or

③ equivalent fire-extinguishing systems deemed by the Administration to provide an equivalent level of protection.

(2) Portable fire extinguishers of sufficient number are to be provided in the enclosed spaces storing the diving system, one of which is to be placed near the access to the enclosed spaces. Spare charges are to be provided for 100% of the first ten extinguishers and 50% of the remaining fire extinguishers in the enclosed spaces.

(3) Where fixed gas fire-extinguishing systems are used, the selection of the fire-extinguishing medium is to be such that when the medium is applied in its entirety in the enclosed spaces, the concentration[③] of the toxic gas will not impair human body.

25.5.2.2 Diving systems installed on the open deck

(1) Decks or similar hull structure areas storing diving systems are to be provided with appropriate fire-extinguishing systems.

(2) Fire hoses on the diving support vessel connecting to the fire mains are to be protected as appropriate.

25.5.2.3 Means of cooling

(1) For windows, observation windows or other windows fitted on the manned pressure vessels in the enclosed spaces, means of cooling are to be provided.

(2) Enclosed spaces storing breathing gas cylinders or pressure vessels are to be provided with manually-actuated water spray systems so as to cool the breathing gas cylinders or pressure vessels in case of fire. The application rate on the projected horizontal area is at least $10L/m^2$ per minute. Water mist fire-extinguishing systems may be provided in the enclosed spaces as an alternative, the application rate of which is at least $5L/m^2$ per minute.

25.5.3 Fire detection and alarm systems of the diving system

25.5.3.1 The control panel of the fire detection and alarm system of the diving support vessel is to be installed in the dynamic positioning control station or mooring control station, and repeaters are to be provided in the diving control station and engine room centralized control room.

25.5.3.2 When diving systems are installed in enclosed spaces, the following requirements are to be complied with:

(1) automatic fire detection and alarm systems complying with the FSS Code are to be provided in the enclosed spaces;

(2) the loop or group of the fire detection and alarm systems of the enclosed spaces is to be independent of those of other spaces.

25.5.3.3 When diving systems are installed on the open deck, the following requirements are to be complied with:

(1) the open deck and similar structures of the diving support vessel is to be provided with suitable automatic fire detection and alarm systems;

(2) visual and audible monitoring systems continuously monitored by personnel at the control station may substitute the automatic fire detection and alarm systems on the open deck of the diving support vessel.

25.5.4 Piping systems

25.5.4.1 Piping systems carrying breathing gases under high pressure are not to be arranged inside accommodation spaces, engine rooms or similar compartments.

---

③ The concentration of fire-extinguishing medium is to be lower than the No Observed Adverse Effect Level (NOAEL) as defined in amendments to MSC/Circ.848 (MSC.1/Circ.1267).

25.5.4.2 Piping systems carrying breathing gases are to run as far as practicable apart from electrical cable conduits.
25.5.4.3 Piping systems containing flammable fluids are not to run through enclosed spaces or open deck areas housing breathing gas cylinders.

Section 6 UNMANNED REMOTELY OPERATED VEHICLE SUPPORT

25.6.1 General requirements

25.6.1.1 An unmanned underwater vehicle which can only be operated with remote controls. Such vehicles are divided into, according to the pattern of control, tethered ones operated through umbilical and non-tethered ones operated through sound wave.
25.6.1.2 Unmanned remotely operated vehicles and their relevant supporting systems (the handling system, control station, etc.), if complying with the requirements of this Section, may be assigned the notation ROVS upon request of the ship owner and ship operator.

25.6.2 Handling systems

25.6.2.1 Handling systems of unmanned remotely operated vehicles are to comply with the relevant requirements of ISC Rules for the Construction and Classification of Diving Systems and Submersibles.
25.6.2.2 Handling systems of unmanned remotely operated vehicles are to be so arranged as to minimize the possibility of any interference with propellers, thrusters or anchors of the support vessel.
25.6.2.3 Safe storage location with fastening arrangements is to be provided for remotely operated vehicle being securely stowed on the support vessel while they are not in operation.
25.6.2.4 The relevant hull structure strengthening of the unmanned remotely operated vehicle as well as the hull structure strengthening beneath the handling system foundation are to comply with the requirements of 25.4.1 of this Chapter.

25.6.3 Control stations

25.6.3.1 The control station for the unmanned remotely operated vehicle is to be securely fastened at a location close to and in sight of the launch and recovery location.
25.6.3.2 The control station for the unmanned remotely operated vehicle is to provide direct communication to the following positions:
(1) the vessel's control station;
(2) the control station of any other underwater vehicle;
(3) the control station for subsea equipment on the offshore engineering support vessel, such as the control station for oil well accident handling.

Section 7 SURVEY, INSPECTION AND TESTING

25.7.1 General requirements

25.7.1.1 The installation of the diving system and/or ROV system on the diving support vessel is to be to the satisfaction of the attending surveyor.
25.7.1.2 The diving system and/or ROV system on the diving support vessel is to be approved by ISC or other IACS members.
25.7.1.3 Upon installation, the diving system and/or ROV system and their support vessel interfaces as well as the interfaces between the diving systems and/or ROV systems installed on the support vessel are to be functionally tested to the satisfaction of the attending surveyor.

CHAPTER 26 ADDITIONAL REQUIREMENTS FOR INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

Section 1 GENERAL PROVISIONS

26.1.1 Application

26.1.1.1 Unless provided otherwise, this Chapter applies to :

(1) existing ships where an application for approval of BWMS is made on or after 1 July 2022;

(2) a ballast water management system which is installed in ships contracted for construction on or after 1 July 2022.

26.1.1.2 In addition to the requirements contained in International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (hereinafter referred to as the BWM Convention), the requirements of this Chapter for the installation of ballast water management systems above are to be complied with.

26.1.1.3 Ballast Water Management System is also to meet the additional requirements for fire safety measures as specified in appendix 1 to this Chapter.

26.1.2 Definitions

26.1.2.1 For the purpose of this Chapter:

(1) Ballast water management system (hereinafter referred to as 'BWMS') means any system which processes ballast water such that it meets or exceeds the ballast water performance standard in regulation D-2 of the BWM Convention. The BWMS includes ballast water equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in Table 26.1.2.1 of this Chapter. Applicability of the requirements for each BWMS technology is in accordance with Table 26.1.2.2 of this Chapter.

(2) Cargo area of tankers is defined in:

① for tankers to which regulation 1.6.1 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) (hereinafter the same) applies, regulation 3.6 of SOLAS Chapter II-2;

② for chemical tankers, Paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460(101);

③ for gas carriers, Paragraph 1.2.7 of the IGC Code as amended by IMO resolutions up to MSC.441(99); and

④ for offshore support vessels, Paragraph 1.3.1 of the IMO Resolution A.673(16) as amended by Resolution MSC.236(82) or Paragraph 1.2.7 of the IMO Resolution A.1122(30), as applicable.

(3) Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation,corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H_2), hydrocarbon gas, oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_2) and chlorine dioxide (ClO_2), etc.

(4) Hazardous area is defined in IEC 60092-502 and means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

(5) Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

(6) Non-hazardous area means an area which is not a hazardous area as defined in above (4).

Categorization of BWMS technologies **Table 26.1.2.1**

BWMS's Technology category*		1	2	3a	3b	3c	4	5	6	7a	7b	8
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N from a N Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N2 generator
Des-infection when ballasting	Making use of active substance		x			In-tank technology: No treatment when ballasting or de-ballasting	x	x	x	x	x	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	x	x	x	x		x				x	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							x				
After-treatment when deballasting	Full flow of ballast water is passing through the BWMS	x									x	
	Injection of neutralizer						x	x	x	x	x	
	Not required by the Type Approval Certificate issued by the Administration		x	x								
Examples of dangerous gas as defined in 26.1.2.1(3)			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2		O_2 N_2

Note:
(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.
(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Footnote: *Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

Applicability of the requirements for each BWMS technology **Table 26.1.2.2**

BWMS's Technology category*→	1	2	3a	3b	3c	4	5	6	7a	7b	8
Requirements of this Chapter ↓	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N from a N Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N2 generator
26.1.1and 26.1.2	x	x	x	x	x	x	x	x	x	x	x
26.2.1.1 to 26.2.1.4	x	x	x	x	x	x	x	x	x	x	x
26.2.1.5			x	x	x						x
26.2.1.6	x	x	x	x	x	x	x	x	x	x	x
26.2.1.7			x	x	x						x
26.2.1.8				x						x	
26.2.1.9	x	x	x	x	x	x	x	x	x	x	x
26.2.2.1（1）				x	x				x	x	
26.2.2.1（2）						x	x	x			
26.2.2.2	x	x	x	x		x	x	x	x	x	
26.2.2.3	x	x	x	x	x	x	x	x	x	x	x
26.2.2.4	x	x	x	x		x	x	x	x	x	
26.2.3.1（1）		x	x			x	x	x	x	x	x
26.2.3.1（2）			x	x	x				x	x	x
26.2.3.1（3）									x	x	
26.2.3.1（4）						x	x	x	x	x	
26.2.3.1（5）						x	x	x			
26.2.3.1（6）			x	x	x				x	x	x
26.2.3.2（1）to（4）		x	x	x	x	x	x	x	x	x	x
26.2.3.2（5）			x			x	x	x	x	x	x
26.2.3.2（6）			x			x	x	x	x	x	x
26.2.3.2（7）			x						x	x	x
26.2.3.2（8）			x			x	x	x	x	x	x
26.2.3.3		x				x	x	x	x	x	
26.2.3.4						x	x	x	x	x	

Section 2 INSTALLATION

26.2.1 General requirements

26.2.1.1 All valves, piping fittings and flanges are to comply with the relevant requirements of Chapter 2, PART THREE of the Rules. In addition, special consideration can be given to the material used for this service with the agreement of ISC.

26.2.1.2 The BWMS is to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected. For new installation or retrofit to existing ships, under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP) the adequacy of the generating plant capacity installed on the vessel is to be demonstrated by an electrical load analysis.

For retrofit installation to exiting ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

26.2.1.3 The BWMS is to be operated in accordance with the requirements specified in the type approval certificate (TAC) issued by the flag Administration or a recognized organization authorized by it. BWMS is to be operated within its Treatment Rated Capacity (TRC) as per the TAC. This may require limiting of ship's ballast pump flowrates.

The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's Type Approval.

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated Capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there is to be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that is not to exceed the maximum TRC of the BWMS.

26.2.1.4 BWMS should be subject to design review by ISC to verify the compliance of the BWMS's manufacturer package with ISC Rules.

Manufacturers of the BWMS may apply for this design review at the type approval process.

In general, monitoring functions of BWMS belongs to system category I under the application of 2.6.3 of Chapter 2, PART SEVEN of the Rules. However, in case a by-pass valve is integrated in the valve remote control system, the by-pass valve belongs to the system category II Ballast transfer remote control system.

The BWMS's components are required to be inspected and certified by ISC at the manufactory including pressure vessels, piping class I or II, filters, switchboards, etc.

26.2.1.5 Where a vacuum or overpressure may occur in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N_2), a suitable protection device is to be provided, e.g. P/V valves, P/V breakers, breather valves or pressure safety relief valve or high/low pressure alarms.

The pressure and vacuum settings of the protection device should not exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location[①②] on the open deck.

Safe location needs to address the specific types of discharges separately.

Signboards or similar warnings at the discharge areas are to be provided.

① inert gas or nitrogen product enriched air from:

a in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any); or

b in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator;

safe locations on the open deck are:

a not within 3 m of areas traversed by personnel; and

b not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

② oxygen-enriched air from:

a in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator; or

b in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices;

safe locations on the open deck are:

a outside of hazardous area;

b not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker

openings, and equipment which may constitute an ignition hazard;

c not within 3 m of areas traversed by personnel; and

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502 §4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092- 502 §4.2.3.1, an additional 1.5 m surrounding the 1.5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker should be located outside the hazardous areas.

Where products covered by IEC 60092-502 are stored on-board or generated during operation of the BWMS, the requirements of this standard are to be followed in order to:

① Define hazardous areas and acceptable electrical equipment, and

② Design ventilation systems.

26.2.1.6 Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in the area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

26.2.1.7 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

(1) FSS Code Ch 15 requirements

① 2.1.2, 2.1.3;

② 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.6, 2.2.4.1, 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 except 2.2.4.5.1.3 and 2.2.4.5.3;

③ 2.3.1.1.2, 2.3.1.2, 2.3.1.4.2, 2.3.1.5, 2.3.1.6, 2.3.2 except 2.3.2.2.1;

④ 2.4.1.3, 2.4.1.4 and 2.4.2;

⑤ For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 2.2.3.1, 2.2.3.2 except 2.2.3.2.6, 2.2.3.2.7 and 2.2.3.2.10.

In general, when applying FSS Code Ch.15 requirements to inert-gas based BWMS, the following modifications are to be considered:

① The terms "cargo tank" and "cargo piping" are to be replaced by "ballast water tank" or "ballast water piping" as relevant.

② The term "cargo control room" is to be replaced by "BWMS control station" as relevant.

③ Requirements for slop tanks on combination carriers are to be disregarded.

④ When applying FSS Code / 15.2.2.4.5.1.1, the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

(2) 4.1.1.2, 4.2.2.1, 4.2.2.3, 4.2.2.7, 4.2.2.8, 4.2.3.4, 4.2.3.5 and 4.2.3.6 of Chapter 4, PART SIX of the Rules. In applying 4.2.3.6, the terms “cargo tanks” and “cargo piping” are to be understood as “ballast tanks” and “ballast piping” respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in (1) prevail.

26.2.1.8 When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of “smart pipe” or “special pipe” in BWMS category 7b or by use of “venturi pipe” in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

26.2.1.9 When it is required to have an automatic shutdown of the BWMS for safety reasons, this must be initiated by a safety system independent of the BWM control system.

26.2.2 Additional requirements for tankers

26.2.2.1 Hazardous area classification is to be in accordance with IEC 60092-502 with due consideration of IACS UI SC274.

(1) BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with FSS Code Ch 15 §2.3.1.1.2.

Note: this requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and 4.2.2 and 4.2.3 of Chapter 4, PART SIX of the Rules apply.

(2) In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of 26.2.1.6 but are not to be located inside the

d not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H_2 generation):

① do not lead to an upgrade of the hazardous area categorization of the cargo pump room,

② are not reactive with the cargo vapours expected to be present in the cargo pump room,

③ are not reactive with the fire-extinguishing medium provided inside the cargo pump room,

④ are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room, and

⑤ are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been prior addressed by suitable counter measures.

Notes:

① In-line full flow electrolysis BWMS (category 4) could be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.

② For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".

③ Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".

26.2.2.2 In general, two independent BWMS should be required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 5, 6, 7a and 7b) could be accepted are given in appendix 2.

Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with 3.4.14 of Chapter 3, PART SIX of the Rules, the ballast water of the Fore Peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

26.2.2.3 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

(1) Means of appropriate isolation are as follows: Interconnection in between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if appropriate isolation arrangement is provided in accordance with appendix 2 is applied.

Notes:

① The means of appropriate isolation is necessary for the interconnection specified above regardless of the diameter of the piping.

② As indicated in appendix 2, the means of appropriate isolation is necessary for the interconnection specified in said Paragraph in the case of the active substance piping such as N2 gas piping, inert gas piping, neutralizer piping, fresh water piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc. At the discretion of the Classification Society and for active substance piping and neutralizer piping (both not exceeding 50.8 mm) only, alternative isolation arrangements, provided preferably on the open deck, offering enhanced safety and gastightness may be considered for penetration of the bulkhead separating the non-hazardous machinery space from a hazardous area (such as the cargo pump room) at as high an elevation in the machinery space as possible, preferably, just below the main deck. The arrangements are to provide suitable protection measures in addressing the pollution hazards and safety concerns due to the potential migration of hydrocarbon or flammable or toxic liquids or vapours from the hazardous areas.

③ The means of appropriate isolation described above for the interconnection specified in said Paragraph need not be applied to the sampling lines described in Paragraph 26.2.2.4.

① two non-return valves with positive means of closing in series with a spool piece (also mentioned "means of dis-connection" in appendix 2), as indicated in Figure 26.2.2.3(1):

Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.

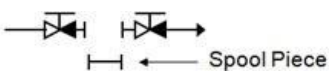


Figure 26.2.2.3(1)
Two Non-return Valves with Positive Means of Closing in Series with a Spool Piece

or:

② two non-return valves with positive means of closing in series with a liquid seal at least 1.5 m in depth, as indicated in Figure 26.2.2.3(2):

Note a: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.
Note b: For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.

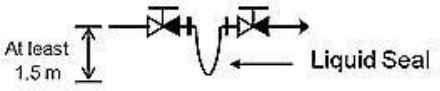


Figure 26.2.2.3(2)
Two Non-return Valves with Positive Means of Closing in Series with a Liquid Seal At Least 1.5 m in Depth

or:

③ automatic double block and bleed valves and a non-return valve with positive means of closing, as indicated in Figure 26.2.2.3(3):

Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.

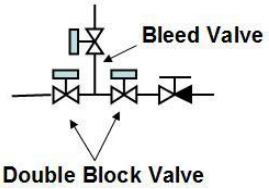


Figure 26.2.2.3(3)
Automatic Double Block and Bleed Valves and a Non-return Valve with Positive Means of Closing

(2) The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.
Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with 3.4.14 of Chapter 3, PART SIX of the Rules, the means of appropriate isolation described in Paragraphs (1) and (2) is not required in between the Fore Peak Tank and the common ballast water piping serving the other ballast water tanks within the cargo area.

26.2.2.4 Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

① for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention, or

② for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system;

are not to be led into a non-hazardous enclosed space outside the cargo area.
However, the sampling lines may lead into a non-hazardous enclosed space outside the cargo area provided the following requirements are fulfilled:

(1) The sampling facility (for BWMS monitoring/control) is to be located within a gas tight enclosure (hereinafter, referred to as a 'cabinet'), and the following ① through ④) are to be complied.

① In the cabinet, a stop valve is to be installed on each sampling line.

② Gas detection equipment is to be installed in the cabinet and the valves specified in ① above are be automatically closed upon activation of the gas detection equipment.

③ Audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which is not to be higher than 30% of the lower flammable limit (LFL). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected.

Note: when the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required.

④ The cabinet is to be vented to a safe location in non-hazardous area on open deck and the vent is to be fitted with a flame arrester.

(2) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

(3) The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.

(4) Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. A warning plate stating "Keep valve closed when not performing measurements" is to be posted near the valves.

Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.
(5) A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).
(6) The samples which are extracted from the ballast water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area and not to discharge to a piping line supplying the spaces located outside the cargo area.

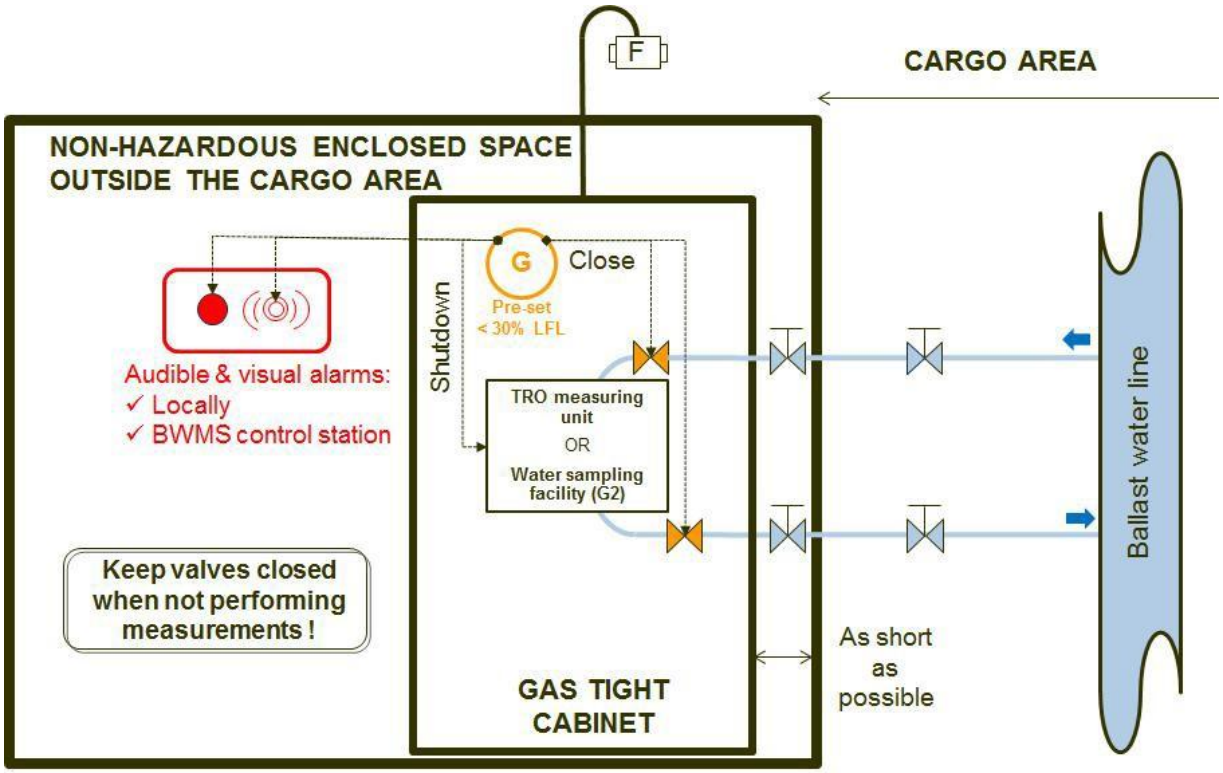


Figure 26.2.2.4 Arrangement of sampling lines led to outside the cargo area

26.2.3 Special requirements for BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8 generating dangerous gas or dealing with dangerous liquids

26.2.3.1 Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:
(1) Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.
The gas detectors should be located as close as possible to the BWMS components where the dangerous gas may accumulate.
For flammable gases and explosive atmosphere including but not limited to H_2, the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1, IEC 60079-29-2, IEC 60079-29-3 and/or IEC 60079-29-4, as applicable.
Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to ISC is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.
(2) In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors are to be positioned at appropriate locations (as required by Paragraph 2.2.4.5.4 of Chapter 15 of the FSS Code as amended by IMO resolutions up to MSC.410(97)) to alarm when the oxygen level falls below 19%. The alarms are to be both audible and visual and are to be activated:
① inside the space;

② at the entry into the space; and

③ inside the BWMS control station.

For BWMS categories 7a and 7b, at least two oxygen sensors are to be positioned at appropriate locations in the following spaces:

① spaces where ozone generators are fitted, or

② spaces where ozone destructors are fitted, or

③ spaces where ozone piping is routed;

to alarm when the oxygen level raises above 23 %. The alarms are to be both audible and visual and are to be activated at the following locations:

① inside the space; and

② at the entry into the space; and

③ inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the oxygen level raises above 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shut-down.

(3) For BWMS categories 7a and 7b, at least one ozone sensor is to be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in 26.2.3.2(3) to alarm when the ozone concentration level raises above 0.1 ppm. The alarms are to be both audible and visual and are to be activated in the BWMS control room. In addition, at least two ozone sensors are to be positioned at appropriate location in the following spaces:

① spaces where ozone generators are fitted, or

② spaces where ozone destructors are fitted, or

③ spaces where ozone piping is routed

to alarm when the ozone concentration level raises above 0.1 ppm. The alarms are to be both audible and visual and are to be activated at the following locations:

① inside the space;

② at the entry into the space; and

③ inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space raises above 0.2 ppm.

(4) Inside double walled spaces or pipe ducts constructed for the purpose of 26.2.3.2 (1) Note ①, sensors are to be provided for the detection of H_2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described in above (1) and (3).

Note: As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts could be provided with an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

(5) For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan shall be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H_2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location[①] on open deck.

(6) The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location[①②] on open deck.

26.2.3.2 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in 26.1.2.1(3) and (5), the following requirements are to be satisfied:

---

① For safe location, refer to requirements of paragraph 26.2.3.2(3).

①② For safe location, refer to requirements of paragraph 26.2.1.5.

Notes:

① This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.

② The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.

(1) Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by Table 2.1.5.1 of Chapter 2, PART THREE of the Rules. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in Chapter 2, PART THREE of the Rules. Mechanical joints, where allowed, are to be selected in accordance with Table 2.5.3.1(3) of Chapter 2, PART THREE of the Rules.

Notes:

① For piping class II with special safeguards conveying dangerous gas like hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct.

② For piping class II with special safeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.

③ Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of Appendix 1to Chapter 2, PART THREE of the Rules apply.

(2) The length of pipe and the number of connections are to be minimised.

(3) Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of 26.2.3.2(1) Note ① are to be equipped with mechanical exhaust ventilation leading to a safe location[①②] on open deck.

(4) The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.

(5) Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

(6) H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) are not to be routed through accommodation spaces, services spaces and control stations.

(7) O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) are not to be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of 26.2.3.2(1) Note ① and provided with suitable gas detection as described in 26.2.3.1(4) and mechanical exhaust ventilation as described in 26.2.3.2(3).

(8) The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

26.2.3.3 For BWMS using chemical substances or dangerous gas which are stored on-board for either:

① storage or preparation of the active substances (BWMS categories 2 and 6), or

---

① hydrogen by-product enriched gas from:

- in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided);

safe locations on the open deck are:

- not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard;
- not within 3 m of areas traversed by personnel; and
- not within 5 m of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous zone 1 plus an additional 1,5 m surrounding the 3 m hazardous zone 1 is to be categorized hazardous zone 2.

Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

② For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O_3 destructor device (ODS) can be considered as oxygen-enriched air provided that:

- the ODS are duplicated; and
- the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS; and - ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.

If one of the above 3 conditions is not fulfilled, the safe location from ODS on open deck are:

- outside of hazardous area;
- not within 3 m of any source of ignition;
- not within 6 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

② storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b), or

③ recycling the wastes produced by the BWMS (BWMS category 2),

procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20 "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process", and the following measures are to be taken as appropriate:

(1) The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.

(2) Chemical substances (even if they are not defined as dangerous liquid in the sense of 26.1.2.1(4)) and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:

① for independent tanks permanently fixed onboard containing dangerous liquids (e.g. sulfuric acid H_2SO_4) or dangerous gas (e.g. oxygen O_2): Chapter 6, PART THREE of the Rules as applicable to pressure vessels;

② for independent tanks permanently fixed onboard not containing dangerous liquid (e.g. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous gas (eg. nitrogen N_2): Chapter 6, PART THREE of the Rules as applicable to pressure vessels or other industry standard recognized by ISC.

(3) When the chemical substances are stored inside integral tanks, the ship's shell plating is not to form any boundary of the tank.

(4) Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location[1&2] on open deck.

(5) An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.

(6) Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings.

Further to the safety and/or pollution assessment of the concerned chemical substances, consideration should be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement should be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in 26.1.2.1(3) and (5).

Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for this assessment.

26.2.3.4 A risk assessment is to be conducted in a generic manner during the design review mentioned in 26.2.1.4 and submitted to ISC for approval for the following BWMS categories:

- BWMS category 4: in all cases;
- BWMS category 5: in all cases;
- BWMS category 6: when one of the MSDS indicates that the chemical substance stored on-board is either flammable, toxic, corrosive or reactive;
- BWMS category 7a and 7b: in all cases.

Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used as a reference for this assessment.

(1) The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:

- FMEA, FMECA, HAZID, HAZOP, etc.
- ISO 31010 – Risk Assessment Techniques
- IACS Recommendation Rec. 146
- Rules of the Classification Society for risk assessment techniques

(2) The risk assessment should ensure that the package supplied by the BWMS's manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in 26.2.1.4 but that need to be implemented during the installation on-board.

Appendix 1 ADDITIONAL FIRE SAFETY MEASURES RELATED TO THE INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

Section 1 GENERAL REQUIREMENTS①

1.1 Application

1.1.1 This Appendix details fire safety measures, in addition to that required by SOLAS II-2, related to the installation of Ballast Water Management Systems onboard any ship. This section is to be read in conjunction with Chapter 26, PART EIGHT of the Rules.

1.1.2 The requirements of this Appendix apply for BWMS technologies as listed in Table 26.1.2.1. BWMS with alternative technologies are to be specially considered.

1.2 Definitions

1.2.1 Airlock

An airlock is a space enclosed by gastight steel bulkheads with two gastight doors spaced not more than 2.5 m apart. The doors are to be self-closing without any holding back arrangements. Air locks are to have mechanical ventilation and are not to be used for other purposes. An audible and visual alarm system to give a warning on both sides of the air lock is to be provided to indicate if more than one door is moved from the closed position. The air lock space is to be monitored for dangerous gas as defined in 26.1.2.1(3) of Chapter 26, PART EIGHT of the Rules.

1.2.2 Ballast Water Management System (BWMS)

Ballast Water Management System means any system defined in paragraph 26.1.2.1 of Chapter 26, PART EIGHT of the Rules.

---

① This Section is to be uniformly implemented for:

i) existing ships, where the application for approval for the [installation] plans of BWMS is dated on or after 1 July 2022; or

ii) BWMS installed on the new ships contracted for construction on or after 1 July 2022.

1.2.3 Ballast Water Management Room (BWMR)
A Ballast Water Management Room is any space containing equipment belonging to the Ballast Water Management System. A space containing remote controls for the BWMS or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR for the purposes of this Section.
1.2.4 BWMS storing, introducing or generating chemicals.
In general, BWMS storing, introducing or generating chemicals refer to:
(1) In-line flocculation (cat.2 as per Table 26.1.2.1),
(2) Chemical injection (cat.6 as per Table 26.1.2.1) and
(3) BWM technologies using neutralizers injection (cat.4, 5, 6 and 7 as per Table 26.1.2.1)
BWMS that do not store, introduce or generate toxic or flammable chemicals may be specially considered as detailed in Table 1.1.2.1 below.

Requirements that may be reduced for BWMS storing, introducing or generating chemicals depending on the chemicals

Table 1.1.2.1

Requirement	Conditions to be met before reducing the requirement
2.3.4	The stored chemicals are neither toxic nor flammable
3.1.1	The BWMS does not use any flammable or toxic chemical substances
3.3.1	No dangerous gas as defined in 26.1.2.1(3) will be generated by the BWMS
6.1.1	No toxic chemical is stored and no toxic gas will be generated by the BWMS
7.1.1 7.1.3 7.1.6	No toxic chemical is used or will be generated by the BWMS

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and "safety hazard'' as listed in Ch.17 of IMO IBC code are to be considered for this purpose.
Note: Chemicals include additives for BWMS.

Section 2 FIRE CATEGORIZATION

2.1 General
2.1.1 BWMR shall be classified as follows for the purpose of applying the requirements of SOLAS Chapter II-2:
(1) BWMR containing oil-fired inert gas generators (i.e. BWMS cat.3b and 3c as per Table 1.1.2.1) is to be treated as machinery spaces of category A;
(2) Other BWMR shall be considered as other machinery spaces and shall be categorized, depending on the ship type (10) or (11) according to SOLAS II-2/9.2.2.3 or (7) according to SOLAS II-2/9.2.2.4, II-2/9.2.3 and II-2/9.2.4.

2.2 BWMS located in the cargo area of tankers
2.2.1 Notwithstanding the above, where a BWMS is located in the cargo area of a tanker as allowed by Chapter 26, PART EIGHT of the Rules, the BWMR shall be categorized as (8), a cargo pump-room, according to SOLAS II-2/9.2.4.2.2 for determining the extent of fire protection to be provided.
Note: The cargo area of a tanker is defined in para 26.1.2.1(2) of Chapter 26, PART EIGHT of the Rules.

2.3 Storage of chemicals
2.3.1 Spaces where the storage of liquid or solid chemicals for BWMS is intended shall be categorized as store-rooms for the purpose of applying the requirements of SOLAS Chapter II-2, i.e.:
(1) On passenger ships carrying more than 36 passengers:
① "Other spaces in which flammable liquids are stowed" as defined in SOLAS II-2/9.2.2.3.2.2(14), if flammable products are stored;
② "Store-rooms, workshops, pantries, etc." as defined in SOLAS II-2/9.2.2.3.2.2(13) otherwise.
(2) On other ships:
① "Cargo pump-rooms" as defined in SOLAS II-2/9.2.4.2.2.2(8) if located in the cargo area of a tanker;

② “Service spaces (low risk)” as defined in SOLAS II-2/9.2.2.4.2.2(5), SOLAS II-2/9.2.3.3.2.2(5) or II-2/9.2.4.2.2.2(5) if the surface area is less than 4m2 and if no flammable products are stored;

③ “Service spaces (high risk)” as defined in SOLAS II-2/9.2.2.4.2.2(9), SOLAS II-2/9.2.3.3.2.2(9) or II-2/9.2.4.2.2.2(9) otherwise.

Note: It is understood that only chemical injection (cat.6 as per Table 26.1.2.1), in-line flocculation (cat.2 as per Table 26.1.2.1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Table 26.1.2.1) will require chemical or additive storage.

2.3.2 Where the storage of chemicals is foreseen in the same room as the ballast water management machinery, this room shall be considered both as a store-room and as a machinery space in line with 2.1.

2.3.3 When the chemical substances are stored inside integral tanks, the ship's shell plating shall not form any boundary of the tank.

2.3.4 Tanks containing chemicals shall be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces should be considered as satisfying this provision.

Section 3 BWMR LOCATION AND BOUNDARIES

3.1 BWMS using chemical substances

3.1.1 For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms are to be located not less than 3m from entrances, air inlets and openings to accommodation spaces. This requirement need not apply in case the BWMS is located in the engine room.

3.2 Ozone-based BWMS

3.2.1 Ozone-based BWMS – i.e. cat.7a and 7b - shall be located in dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space is to be through airlock only, except if the only access to that space is from the open deck.

Access to the ozone based BWMR may be provided through the engine room only provided:

(1) Access from the engine room to the BWMR is through airlock and,

(2) An alarm repeater is provided in the BWMR, which will repeat any alarm activated in the engine room.

3.2.2 A sign shall be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room.

3.3 General

3.3.1 BWMR containing equipment for BWMS of the following types shall be equipped with tested gastight and self-closing doors without any holding back arrangements:

(1) BWMS storing, introducing or generating chemical substances

(2) De-oxygenation based on inert gas generator

(3) Electrolysis

(4) Ozone injection

Doors leading to the open deck need however not to be self-closing.

Section 4 FIRE FIGHTING

4.1 Fixed fire-extinguishing system

4.1.1 Where fitted, fixed fire extinguishing systems shall comply with the relevant provisions of the Fire Safety Systems Code.

4.1.2 Ozone-based BWMS

BWMR containing equipment related to ozone-based BWMS shall be provided with a fixed fire extinguishing system suitable for category A machinery spaces and capable of manual release.

4.1.3 Where a fixed fire-extinguishing system is provided in the BWMR, it should be compatible with the BWMS and the chemical products that are used, produced or stored in the BWMR. Specific attention shall be paid to potential chemical reactions between the fire extinguishing medium and chemical products used for water treatment. Especially, water-based fire-extinguishing systems should be avoided in case of sulfuric acid storage.

4.1.4 Foam fixed fire-extinguishing system

For all kinds of BWMS, in case a foam fire extinguishing system is installed in the BWMR, its efficiency shall not be impaired by chemicals used by the BWMS where relevant.

4.1.5 Where a fixed fire-extinguishing system is installed in the BWMR, automatic shutdown of the BWMS upon release of the fixed fire extinguishing system shall be arranged. Any need for cooldown necessary for safe shutdown to be considered in the shutdown sequence.

4.1.6 Where BWMS that includes air or O_2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O_2 storage shall be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O_2 storage are led directly to outside the room.

4.2 Portable fire-fighting equipment

4.2.1 There shall be at least one portable fire extinguisher that complies with the provisions of the Fire Safety Systems Code and suitable for electrical fires in the BWMR containing UV type BWMS.

Section 5 FIRE PREVENTION

5.1 Equipment protection

5.1.1 Overcurrent or overvoltage protection is to be installed to protect UV type BWMS.

5.1.2 Electrolysis reactors are to be provided with at least with two independent means of monitoring operation. The monitoring system shall initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected. Requirements for shutdown arrangement are clarified in 26.2.1.9 of Chapter 26, PART EIGHT of the Rules.

Note: If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Chapter 26, PART EIGHT of the Rules. The valve should be positioned to optimally remove gas from the electrolysis reactor.

5.2 Fire detection

5.2.1 A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code shall be installed in spaces containing an inert gas generator or an ozone generator.

5.2.2 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a BWMR containing equipment related to ozone based BWMS.

Section 6 VENTILATION

6.1 Ventilation arrangement

6.1.1 The ventilation systems for BWMR containing BWMS of the following types shall be independent of the ventilation systems serving any other spaces:

(1) BWMS storing, introducing or generating chemical substances;

(2) De-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Table 26.1.2.1);

(3) Electrolysis;

(4) Ozone injection.

6.1.2 The ventilation exhaust for BWMR containing a nitrogen generator shall be located in the lower part of the room in order to efficiently evacuate dangerous gases – as defined in 26.1.2.1(3) of Chapter 26, PART EIGHT of the Rules - heavier than air.

6.1.3 The ventilation exhaust for BWMR containing electrolysis systems shall be located so as to be able to efficiently evacuate dangerous gases – as defined in 26.1.2.1(3) of Chapter 26, PART EIGHT of the Rules - that could be generated during the electrolysis process. Due regard is to be paid to the expected quantity and density of such gases when designing the ventilation exhaust.

6.1.4 The following requirements apply to ventilation ducts serving BWMR for ozone-based BWMS:

(1) The part of the ducts located outside of the BWMR shall be made of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0.075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0.075 m^2 and 0.45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0.45 m^2; and

(2) The ducts shall be suitably supported and stiffened;

(3) The outside openings of the ducts shall be fitted with protective screens of not more than 13 mm square mesh.

6.1.5 The ventilation system for BWMR containing ozone-based BWMS or ventilation system for hydrogen de gas arrangement as required by 26.2.3.1(5) of Chapter 26, PART EIGHT of the Rules shall be interlocked with the BWMS such that:
(1) In case of loss of ventilation (primary and secondary), a visual and audible alarm shall be triggered both inside and outside the BWMR and at a place where a responsible member of the crew is on duty. If the ventilation is not restored after a pre-set time, the BWMS shall then be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence.
(2) It shall not be possible to start the BWMS without the ventilation running.
6.1.6 For ventilation systems serving BWMR and containing or conveying a dangerous gas, relevant requirements in 26.2.3.1 of Chapter 26, PART EIGHT of the Rules are to be satisfied.

6.2 Ventilation rate

6.2.1 An adequate power ventilation system shall be provided in enclosed BWMR.
6.2.2 The ventilation capacity shall be at least 30 air changes per hour where explosive or toxic gases may be generated during operation of the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and "safety hazard'' as listed in Ch.17 of IBC code are to be used as references for identifying those cases.
6.2.3 The ventilation capacity may be reduced as follows:

(1) Flocculation-type BWMS	6 air changes per hour
(2) De-oxygenation, incl. pasteurization and de-oxygenation (cat.3 and cat.8 as per Table 26.1.2.1)	6 air changes per hour
(3) Full flow electrolysis	6 air changes per hour
(4) Side-stream electrolysis	20 air changes per hour
(5) Ozone injection	20 air changes per hour
(6) Chemical injection	6 air changes per hour

Note: More stringent ventilation capacity requirements may arise from other regulations e.g. IBC Code requirements for spaces located in the cargo area.

Section 7 PERSONAL EQUIPMENT

7.1 General Requirement

7.1.1 Suitable protection equipment shall be available onboard for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection equipment shall consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment shall cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.
7.1.2 Work clothes and protective equipment shall be kept in easily accessible places and in special lockers. Such equipment shall not be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment within accommodation spaces if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.
7.1.3 When a BWMS storing, introducing or generating chemicals is installed on board, suitably marked decontamination showers and an eyewash are to be available in a convenient location in close proximately to the BWMS and the chemical store room(s).
7.1.4 An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus may be one of the EEBDs provided in accordance with the requirements of SOLAS II-2/13.
An EEBD need not be required for BWMS of cat.1 as per Table 26.1.2.1.
7.1.5 A personal ozone detector, calibrated as per the manufacturer's specifications, shall be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone.
7.1.6 A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair shall be provided, in addition to those required by SOLAS for firefighting purposes. This two-way radiotelephone apparatus is to be properly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS may release explosive gases, this two-way radiotelephone apparatus is to be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC

Publication 60079.Where the BWMS stores, utilizes or introduces chemicals, the apparatus is to undergo deep cleaning or de-contamination after use.
A two-way portable radiotelephone apparatus need not be required for BWMS of cat.1 as per Table 26.1.2.1.

Appendix 2 INSTALLATION OF ONE SINGLE BWMS ON TANKERS

BWMS's Technologies Categorization **Table 1.1**

BWMS's Technology category* →		1	2	3a	3b	4	5	6	7a	7b
Characteristics↓		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and deoxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank
Des-infection when ballasting	Making use of active substance		x			x	x	x	x	x
	Full flow of ballast water is passing through the BWMS	x	x	x	x	x				x
	Only a small part of ballast water is passing through the BWMS to generate the active substance						x			
After-treatment when deballasting	Full flow of ballast water is passing through the BWMS	x								x
	Injection of neutralizer					x	x	x	x	x
	Not required by the Type Approval Certificate issued by the Administration		x	x						
Examples of dangerous gas as defined in 26.1.2.1(3) of Chapter 26, PART EIGHT of the Rules			(1)	O_2 N_2	CO_2 CO	H_2 Cl_2	H_2 Cl_2	(1)	O_2,O_3,N_2	
Arrangement of one single BWMS	BWMS is located in the outside the cargo area	Not Acceptable	Case 1.2 （2）	Case 1.3a（2）	Case 1.3b	Case 1.4（2）	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b(2)

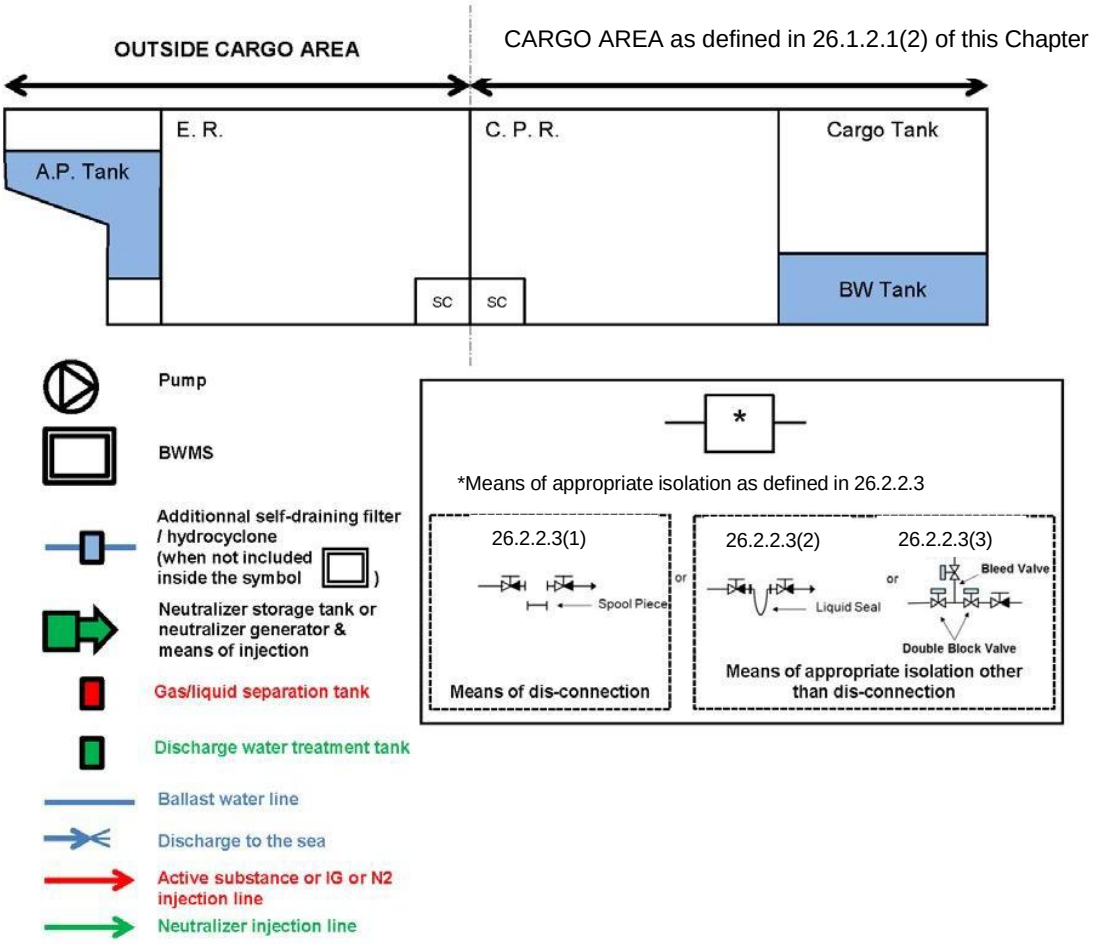
Notes:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) Only Means of dis-connection as described in 26.2.2.3 are to be applied.

(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or deballasting).

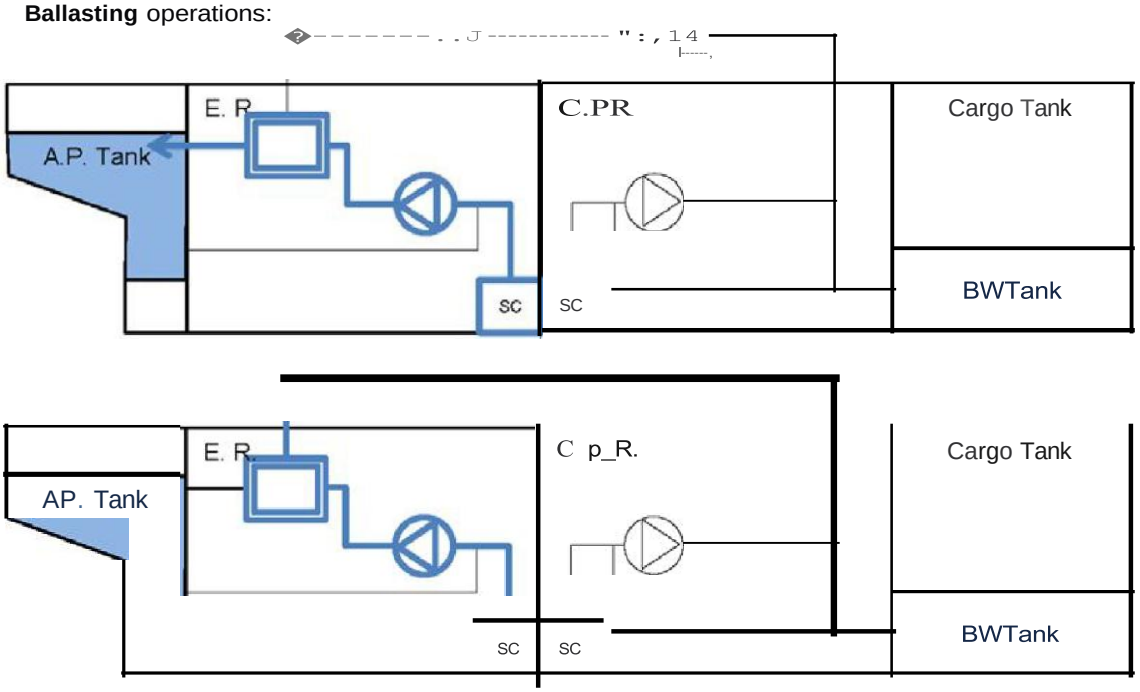
Note: This Appendix does not cover In-tank technologies categories 3c and 8.


OUTSIDE CARGO AREA
CARGO AREA as defined in 26.1.2.1(2) of this Chapter
E. R.
C. P. R.
Cargo Tank
A.P. Tank
SC
SC
BW Tank
Pump
BWMS
Additionnal self-draining filter / hydrocyclone (when not included inside the symbol)
Neutralizer storage tank or neutralizer generator & means of injection
Gas/liquid separation tank
Discharge water treatment tank
Ballast water line
Discharge to the sea
Active substance or IG or N2 injection line
Neutralizer injection line
*
*Means of appropriate isolation as defined in 26.2.2.3
26.2.2.3(1)
Spool Piece
or
26.2.2.3(2)
Liquid Seal
or
26.2.2.3(3)
Bleed Valve
Double Block Valve
Means of dis-connection
Means of appropriate isolation other than dis-connection

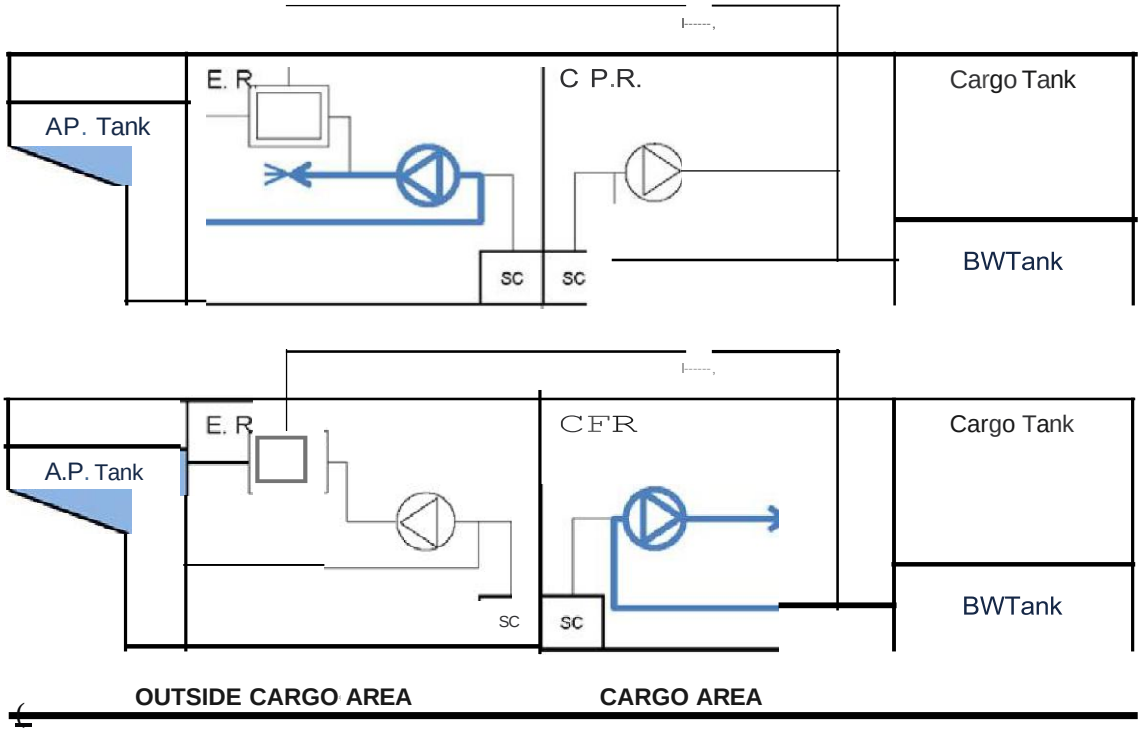
BWMS installed outside the cargo area

Case 1.2 (Technology category 2, Flocculation); and
Case 1.3a (Technology category 3a De-oxygenation with N2 Generator)

Ballasting operations:



De-Ballasting operations:

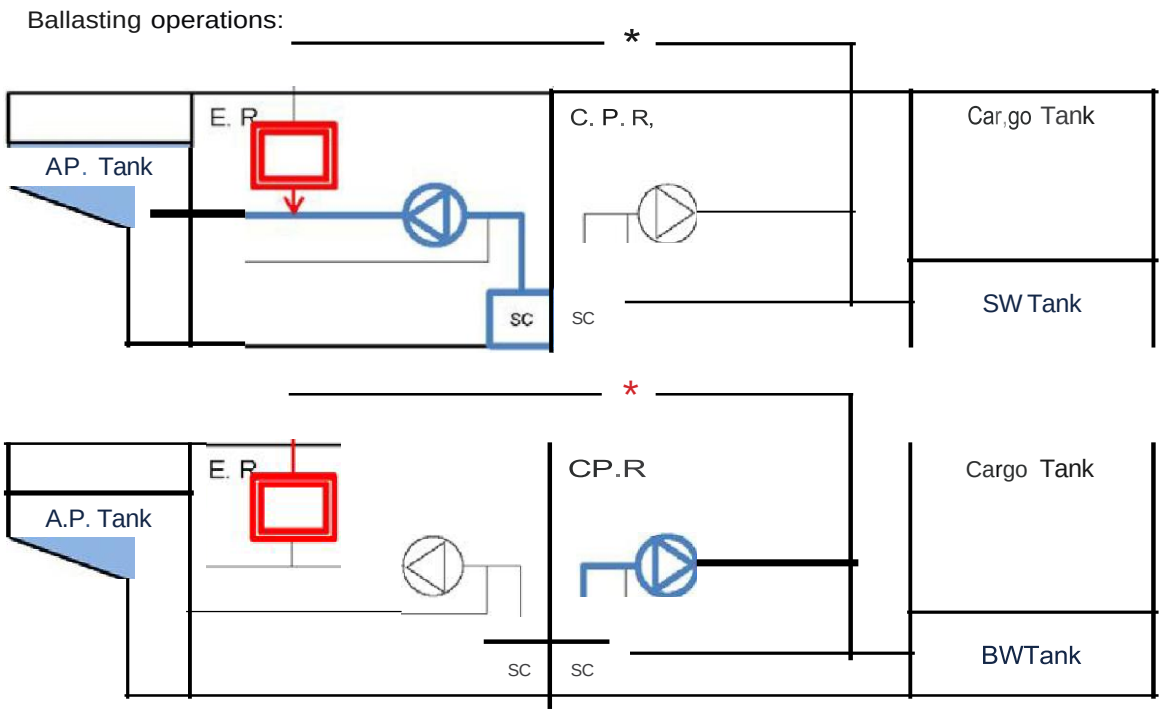


OUTSIDE CARGO AREA **CARGO AREA**

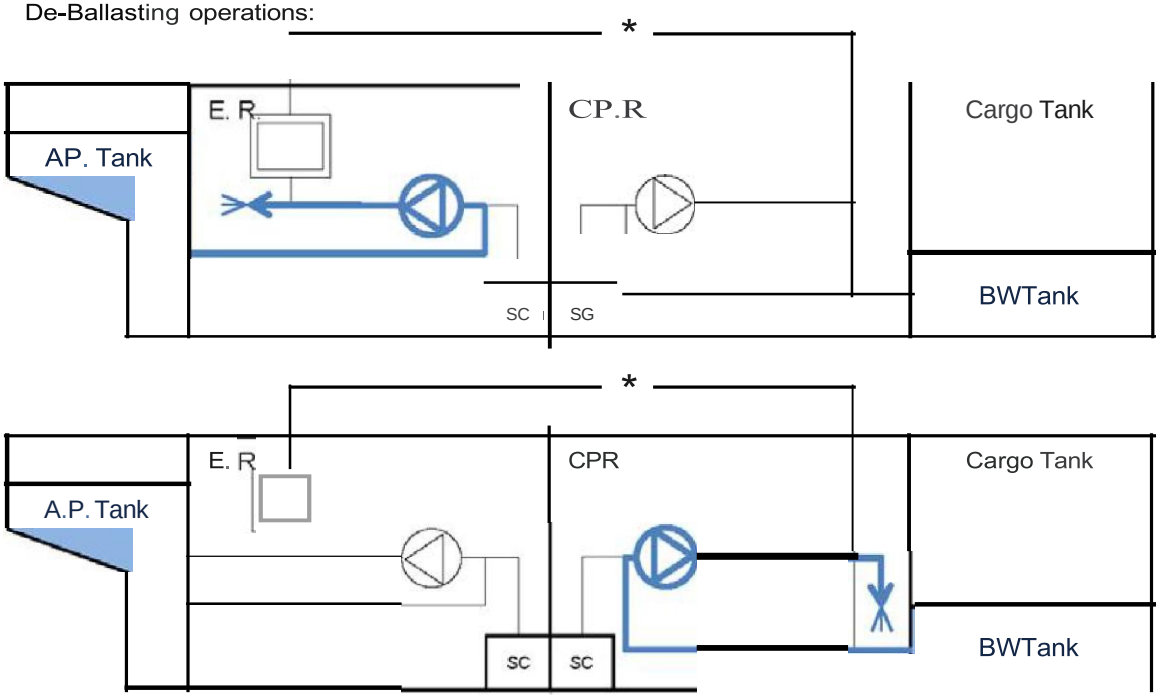
BWMS installed outside the cargo area

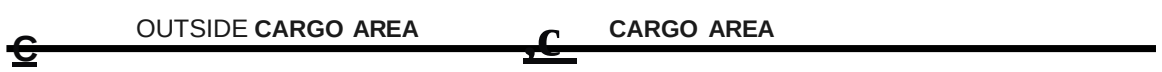
Case 1.3b (Technology category 3b, De-oxygenation with Inert Gas Generator),:

Ballasting operations:



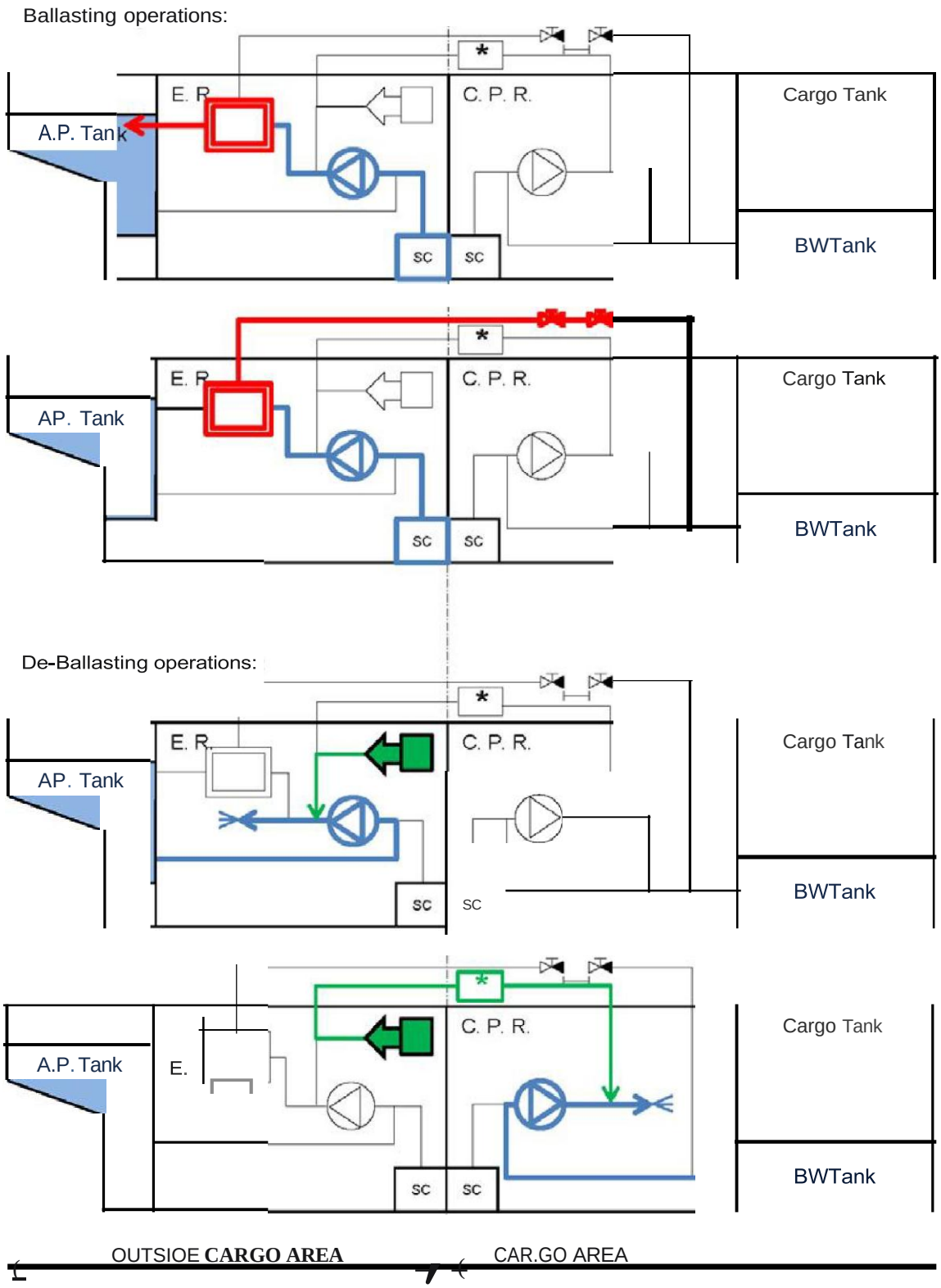
De-Ballasting operations:





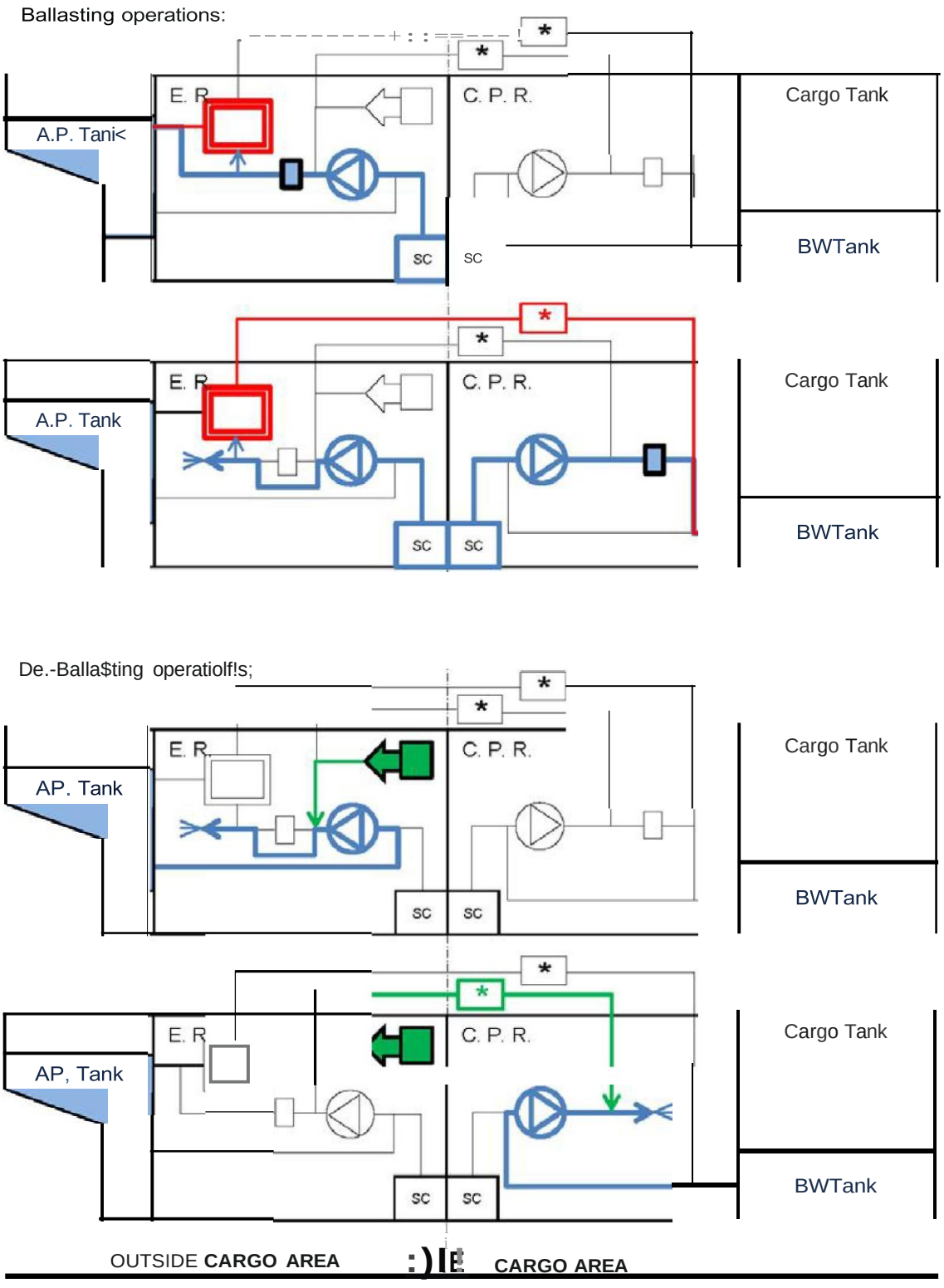
BWMS installed outside the cargo area

Case 1.4 (Technology category 4, Full-flow electrolysis):



BWMS installed outside the cargo area

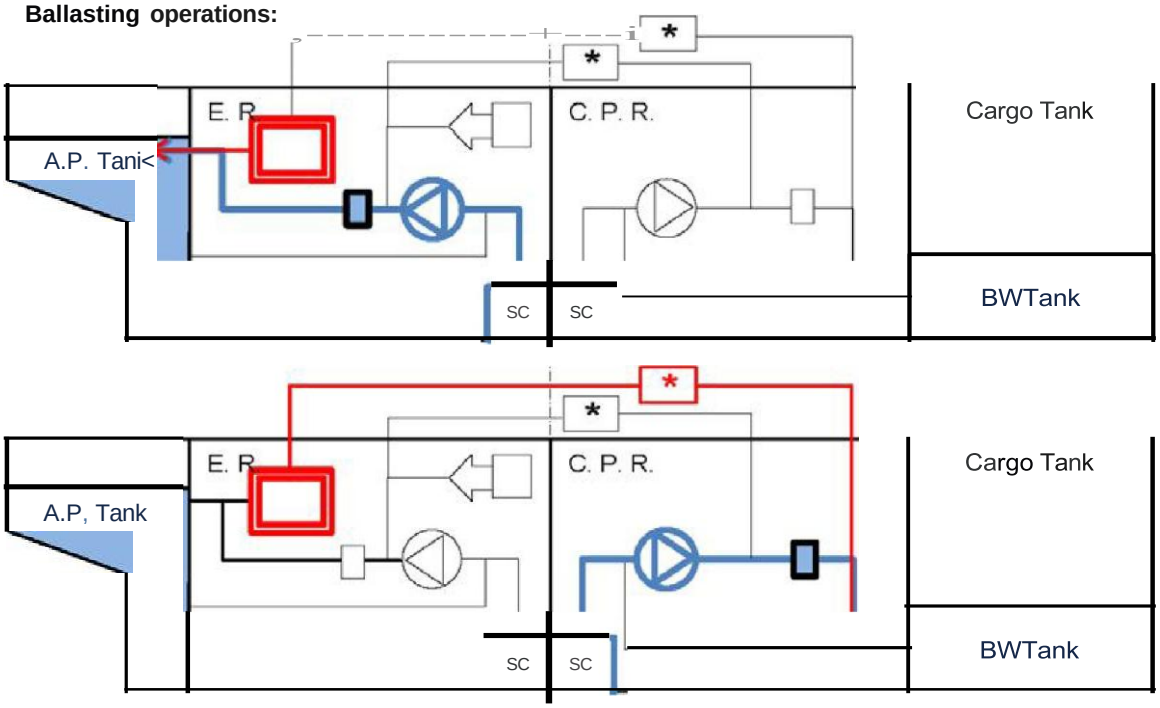
Case 1.5 (Technology category 5, Side-stream electrolysis):



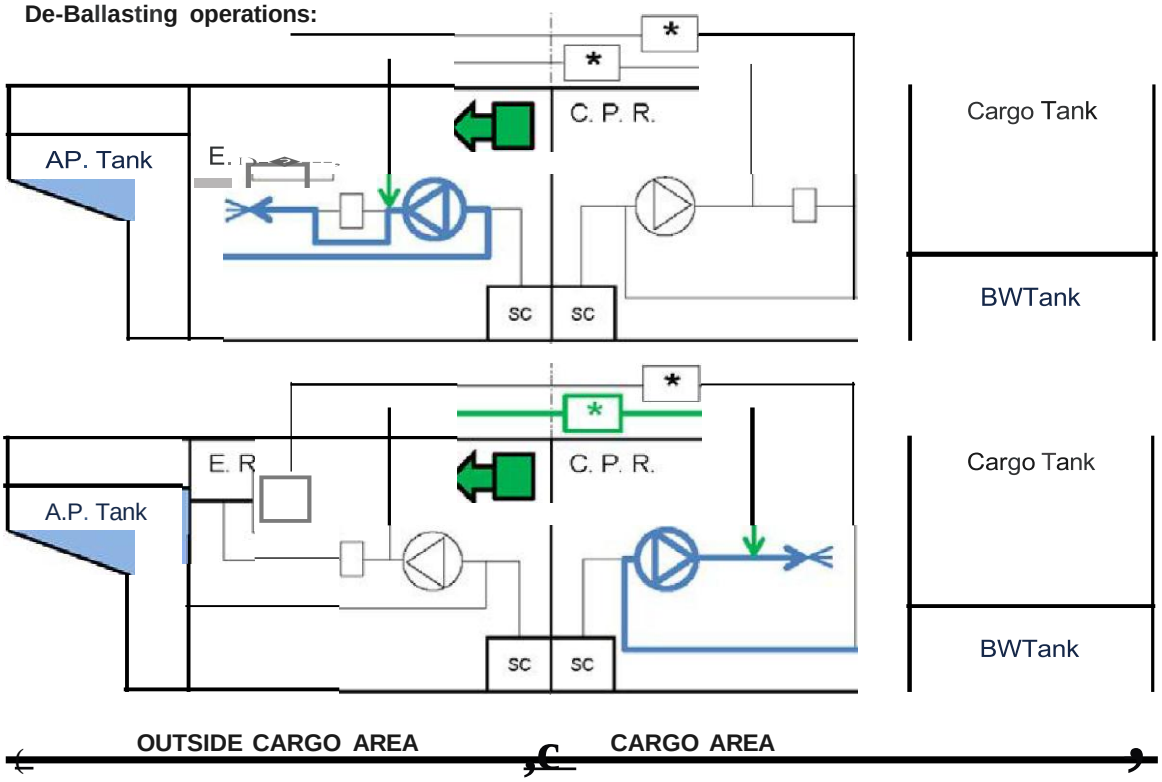
BWMS installed outside the cargo area

Case 1.6 (Technology category 6, stored chemical injection)

Ballasting operations:



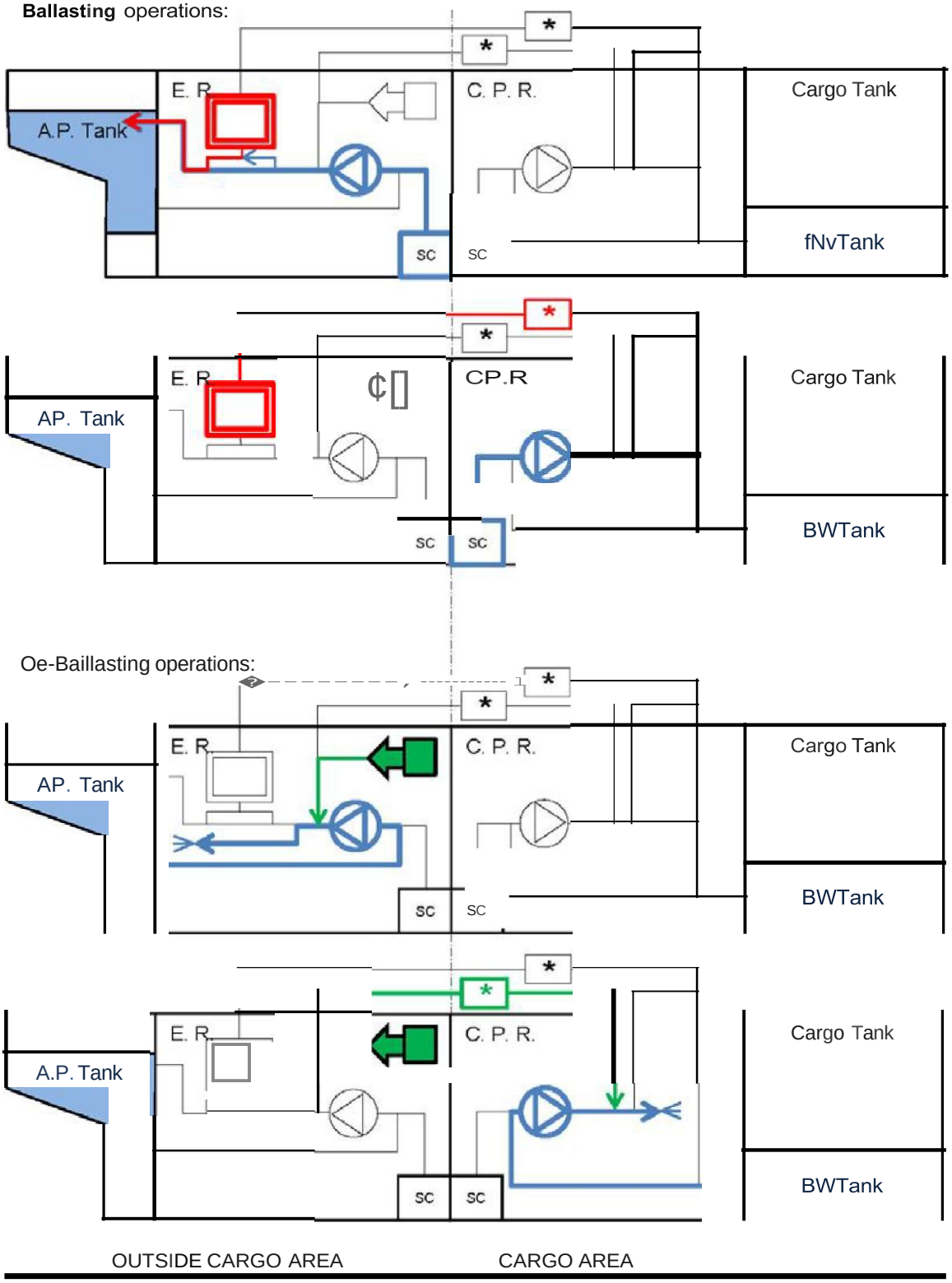
De-Ballasting operations:



BWMS installed outside the cargo area

Case 1.7a (Technology category 7a, Side-stream ozone injection Without gasfliquid separation tank and without discharge water treatment tank);

Ballasting operations:



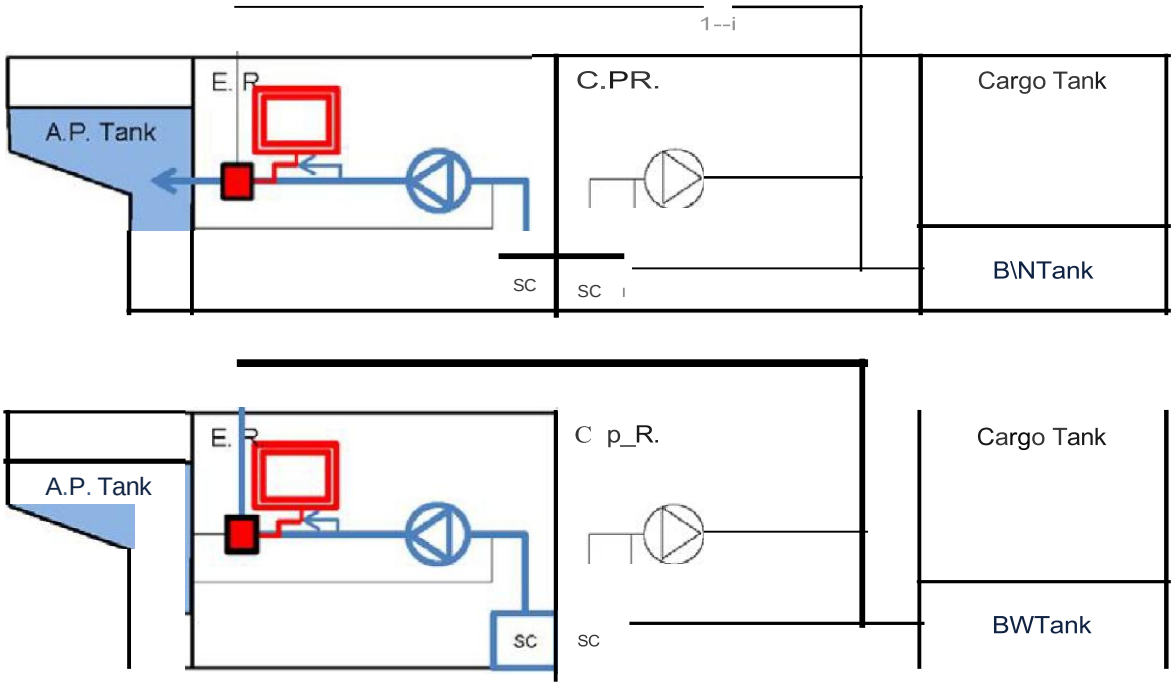
Oe-Baillasting operations:

OUTSIDE CARGO AREA CARGO AREA

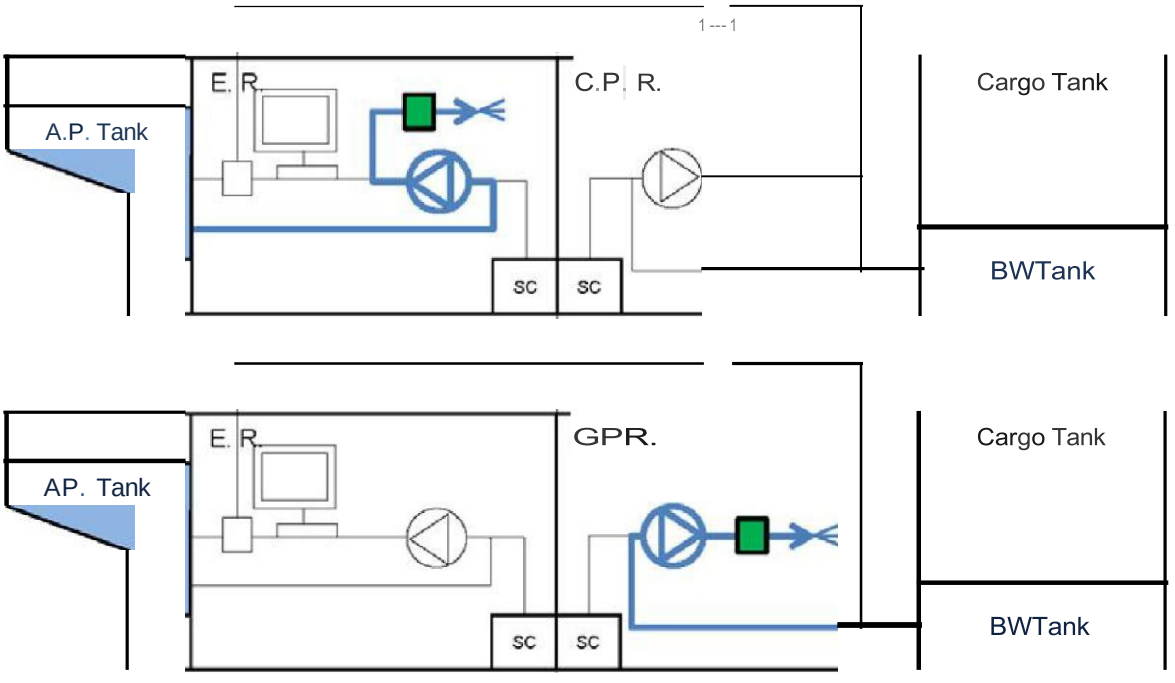
BWMS installed outside the cargo area

Case 1.7b (Technology category 7b, Side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank):

Ballasting operations:



De-Ballasting operations:

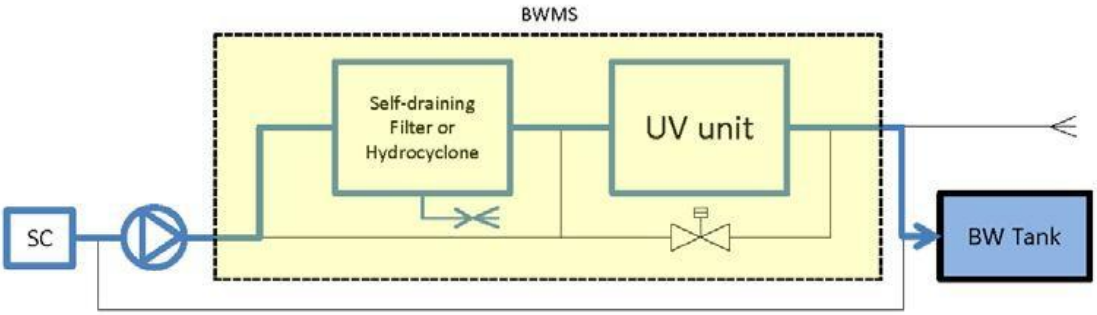


OUTSIDE **CARGO AREA** **CARGO AREA**

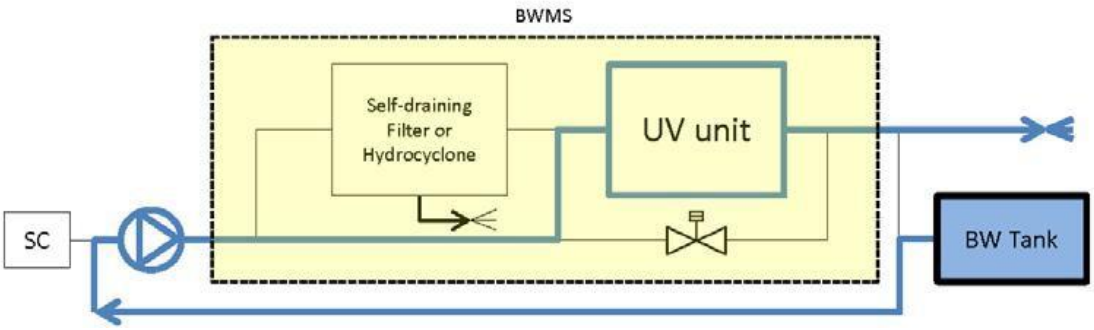
BWMS Technologies categorization

BWMS Technology Group no. 1
In-Line UV
including UV + AOT
Including UV+TiO2)

Ballasting operation:

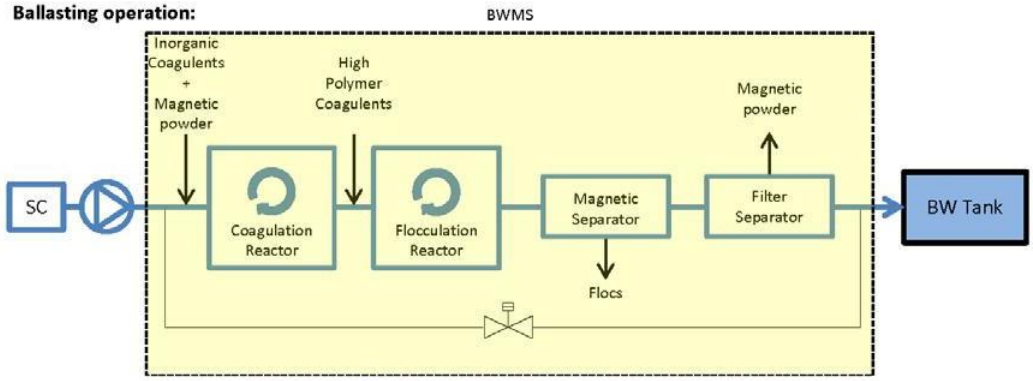


De-ballasting operation:



BWMS Technology Group no. 2
In-Line Flocculation

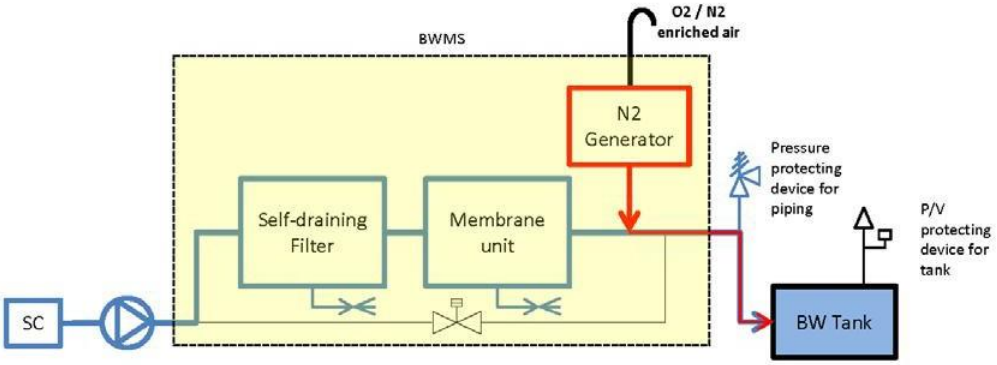
Ballasting operation:



De-ballasting operation: no requirement for after-treatment

BWMS Technology Group no. 3a
In-Line membrane separation and de-oxygenation
(injection of N2 from N2 Generator)

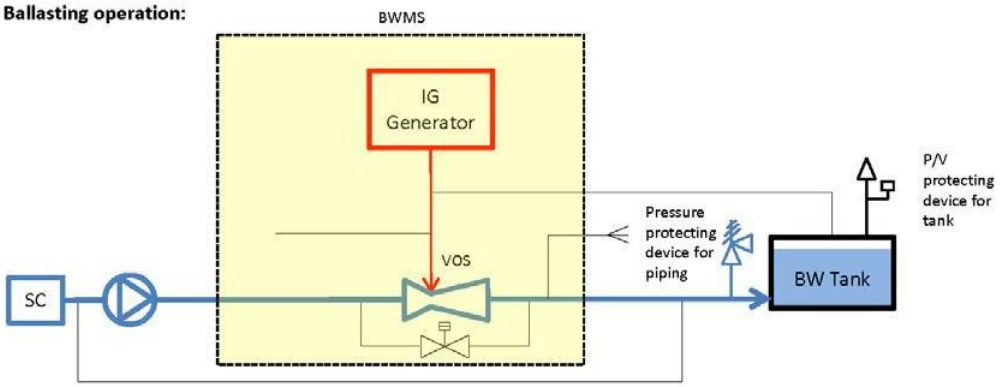
Ballasting operation:



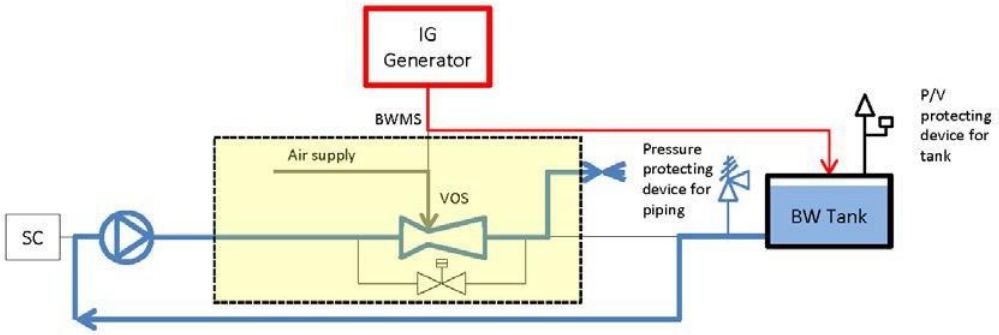
De-ballasting operation: no requirement for after-treatment

BWMS Technology Group no. 3b
In-Line de-oxygenation
(injection of inert gas from either an oil fired inert gas generator or inert gas from treatment of the flue gas from main or auxiliary boilers)

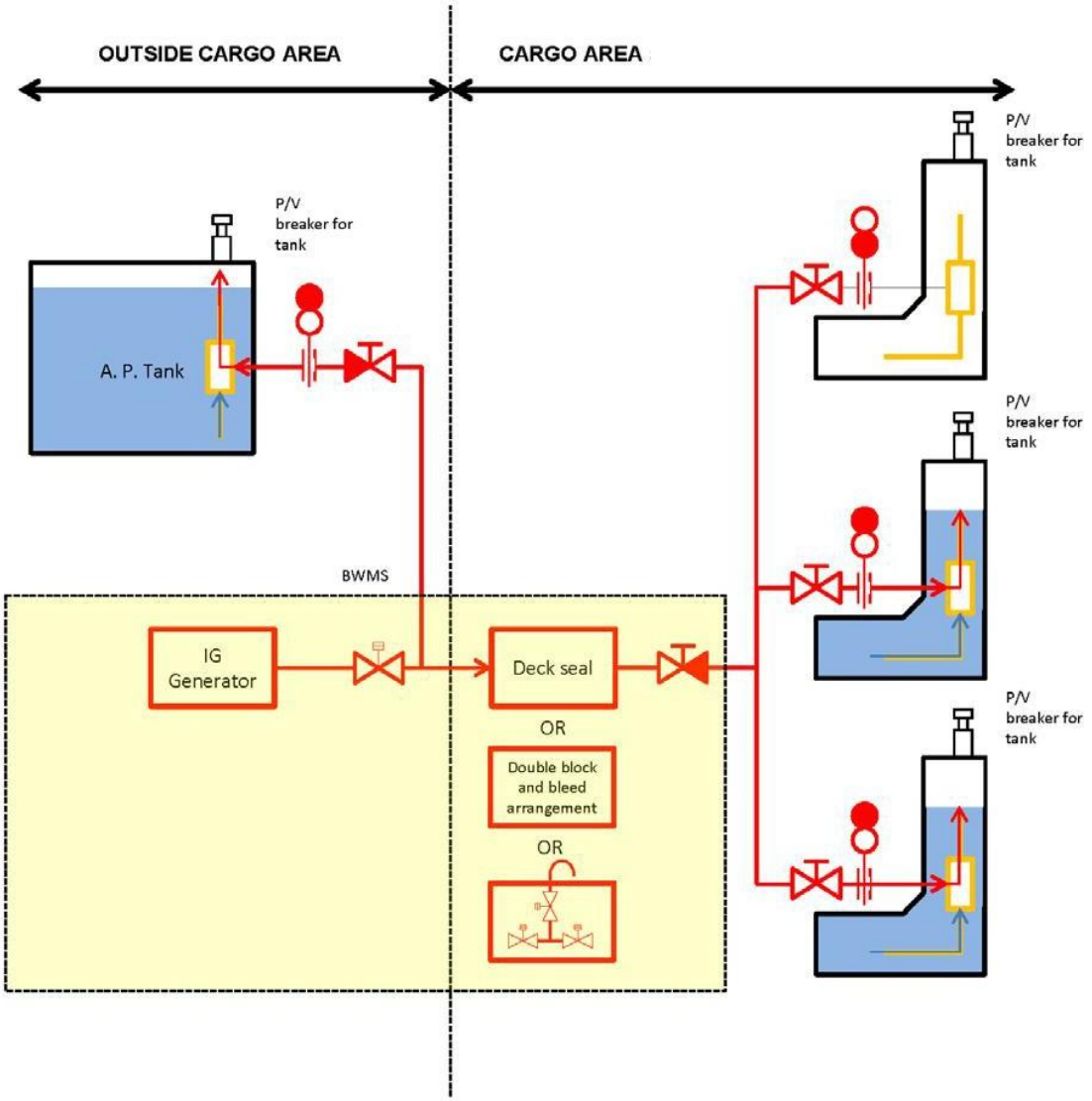
Ballasting operation:



De-ballasting operation:

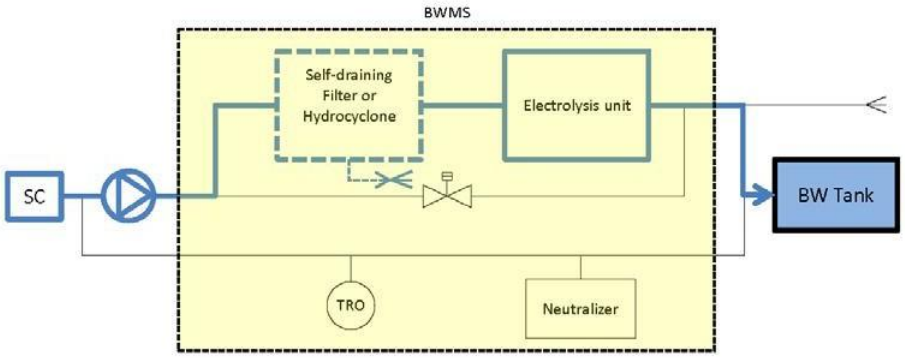


BWMS Technology Group no. 3c
In-tank de-oxygenation with IGG

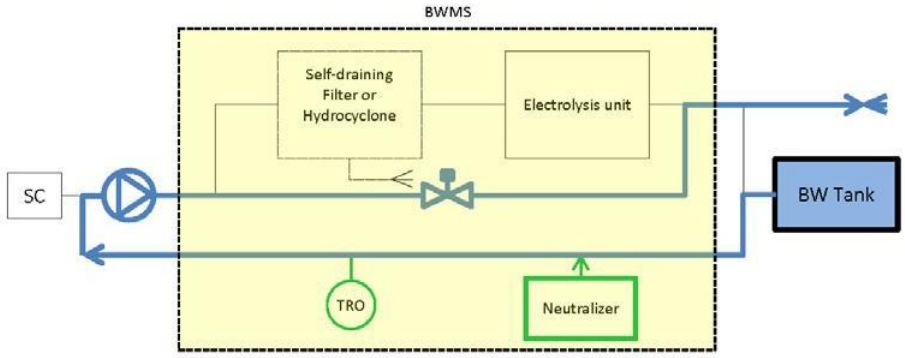


BWMS Technology Group no. 4
In-Line Full flow electrolysis

Ballasting operation:



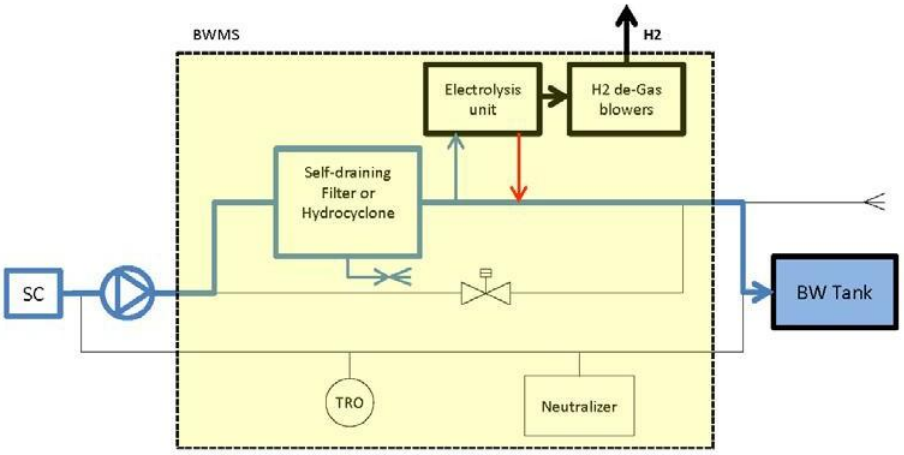
De-ballasting operation:



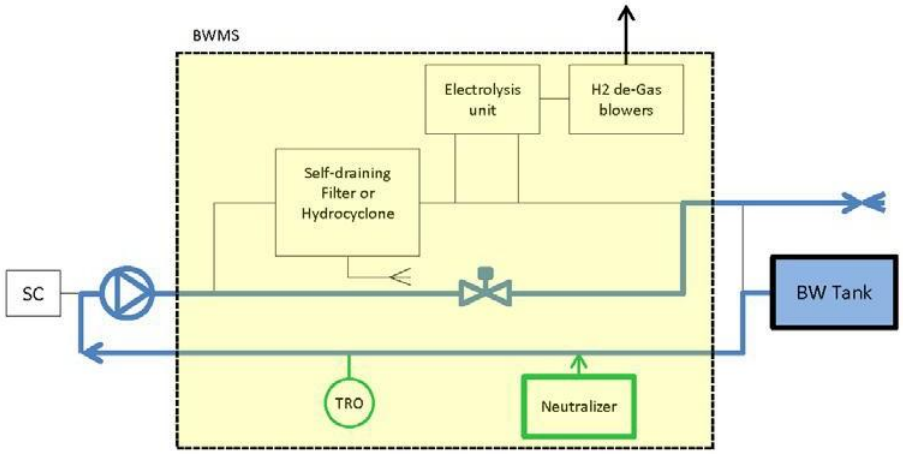
BWMS Technology Group no. 5
In-Line Side-Stream electrolysis (electro-chlorinization)

Note: In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Ballasting operation:

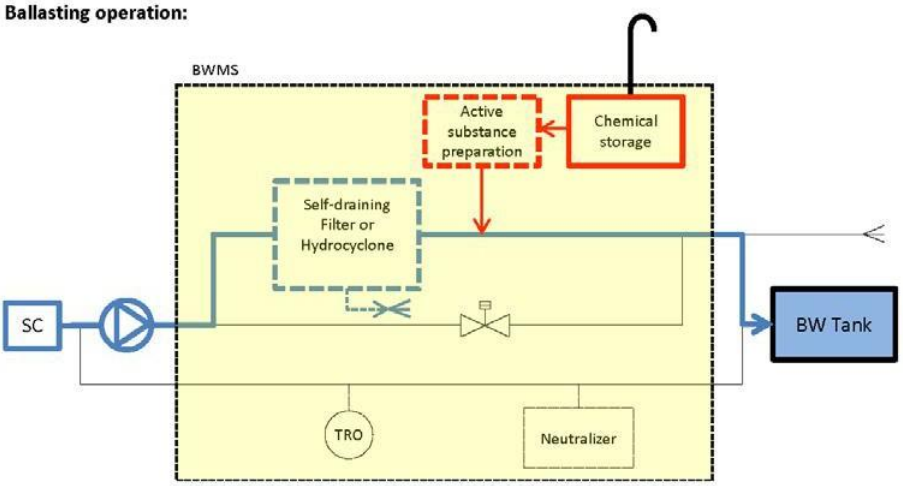


De-ballasting operation:

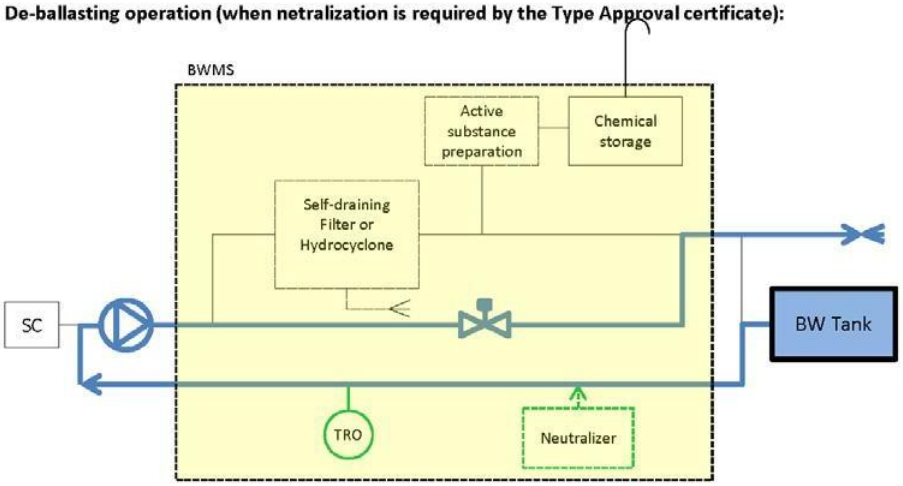


BWMS Technology Group no. 6
In-Line Chemical injection

Ballasting operation:

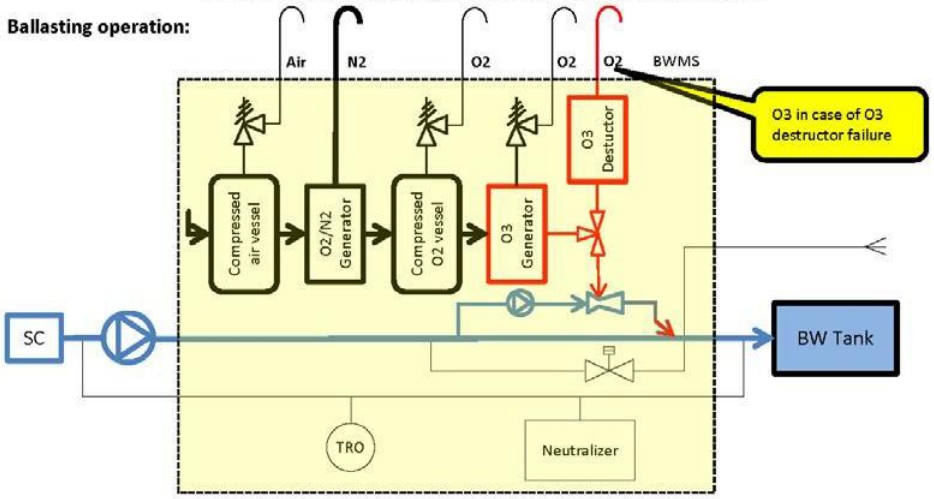


De-ballasting operation (when netralization is required by the Type Approval certificate):

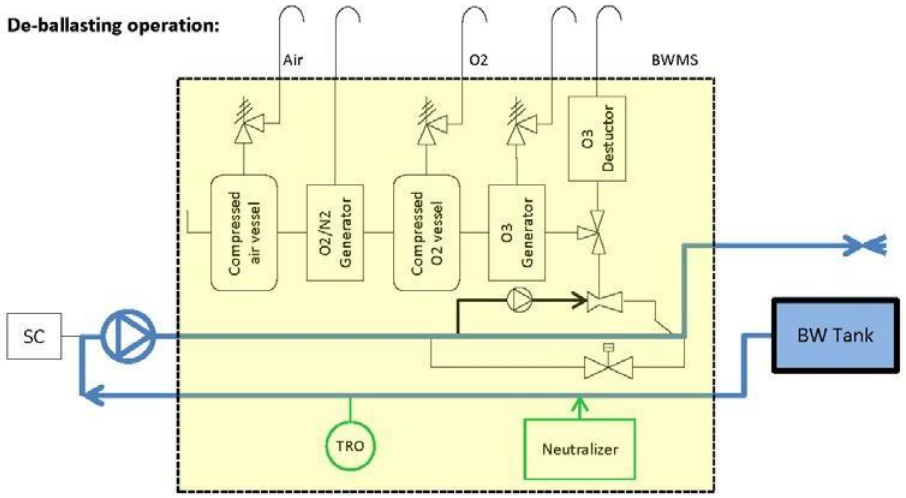


BWMS Technology Group no. 7a
In-Line Side-stream Ozone injection without gas/liquid separation tank and without discharge water treatment tank

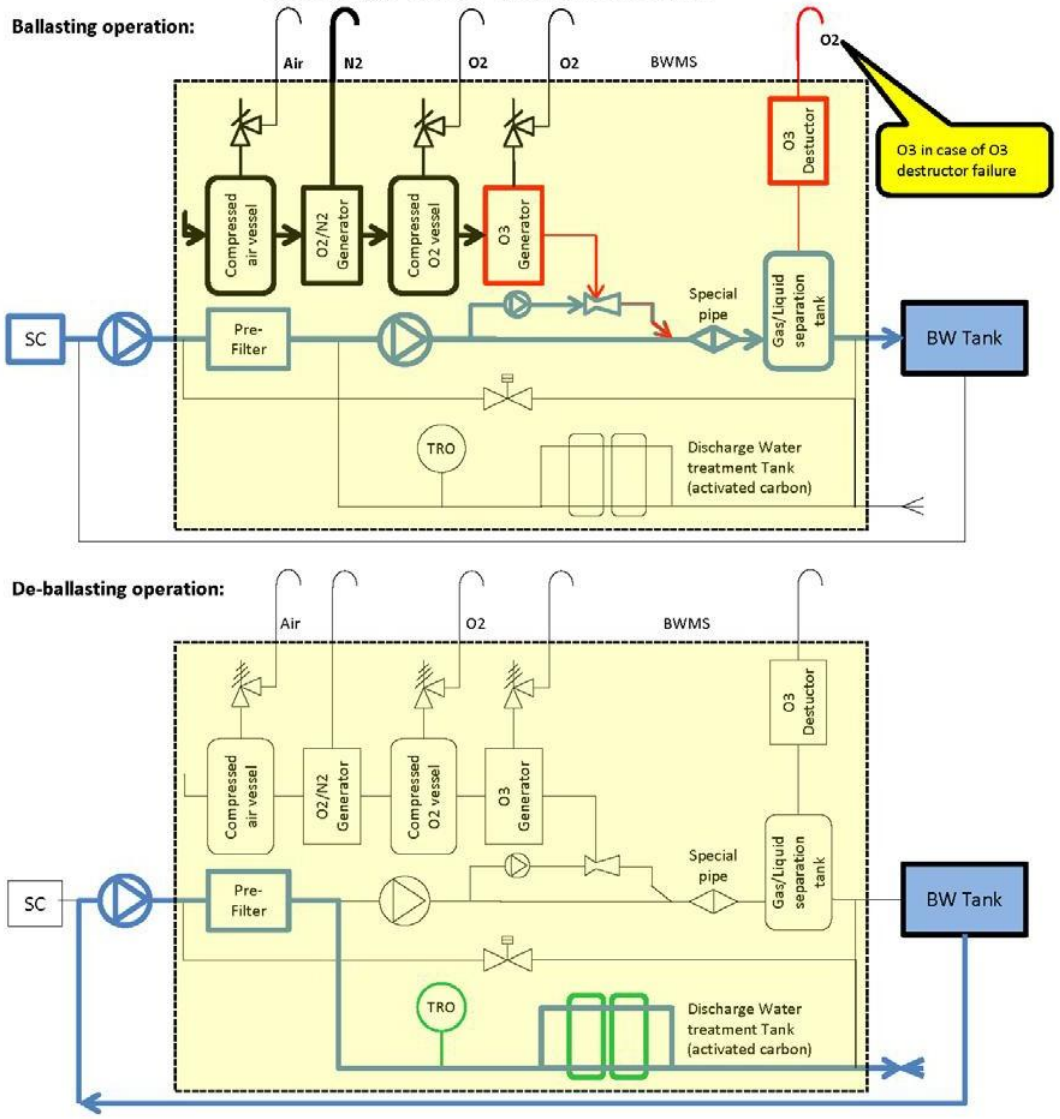
Ballasting operation:



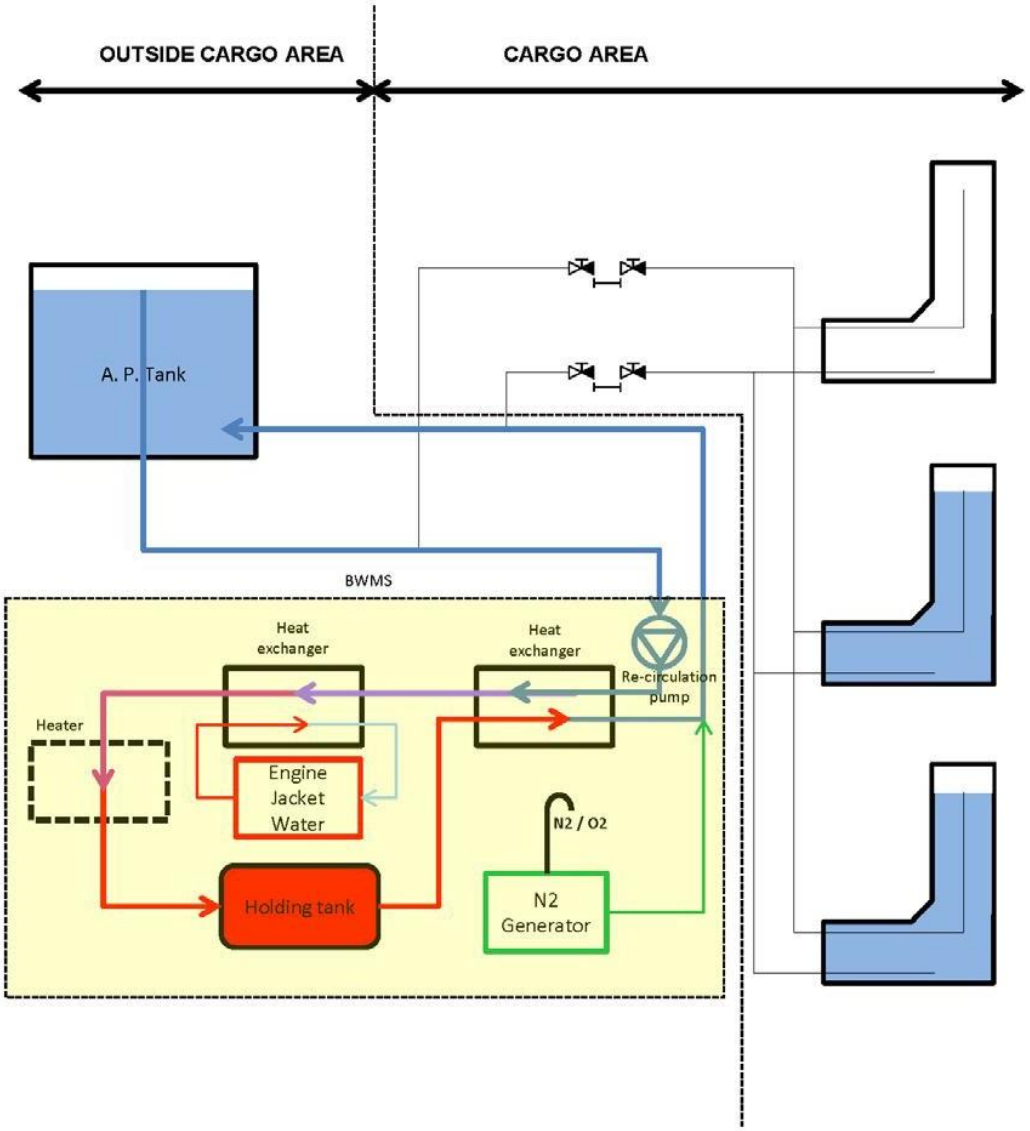
De-ballasting operation:



BWMS Technology Group no. 7b
In-Line Side-stream Ozone injection with gas/liquid separation tank and with discharge water treatment tank



BWMS Technology Group no. 8
In-tank Pasteurization + de-oxygenation with N2 Generator



CHAPTER 27 BOW LOADING SYSTEMS

Section 1 GENERAL PROVISIONS

27.1.1 Application

27.1.1.1 This Chapter applies to oil tankers provided with bow loading systems.

27.1.1.2 Oil tankers provided with bow loading systems are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules

27.1.2 Notation

27.1.2.1 Oil tankers complying with the provisions of Sections 1 to 8 of this Chapter may be assigned the notation: Bow Loading System.

27.1.2.2 Oil tankers complying with the provisions of Section 9 of this Chapter may be assigned the notation: Bow Loading System*.

27.1.3 Definition

27.1.3.1 For the purpose of this Chapter:

(1) Bow loading control station means a control station performing all operations concerning positioning of the ship, operation and monitoring of bow loading safety systems, and monitoring of mooring and loading parameters.

27.1.4 Plans and documents

27.1.4.1 The following plans and documents are to be submitted for approval. If they have been included in plans and documents required for ship's classification, re-submission may be omitted:

(1) general arrangement of bow loading systems, including bow loading control stations;

(2) mooring arrangement of bow loading system areas;

(3) lower hull supporting structure of mooring equipment of bow loading systems;

(4) cargo lines of bow loading systems;

(5) bow loading hydraulic oil systems;

(6) foam fire-extinguishing piping and equipment capacity calculations of bow loading system areas;

(7) water-spraying fire-extinguishing piping and equipment capacity calculations of bow loading system areas;

(8) ventilation piping arrangement of bow loading system areas;

(9) arrangement of the ship showing dangerous zones and spaces of bow loading system areas;

(10) arrangement of electrical equipment in hazardous areas of bow loading system areas;

(11) fire-resisting divisions of bow loading system areas;

(12) fire control plans of bow loading system areas;

(13) schematic diagram of control and monitoring systems of bow loading systems;

(14) schematic diagram of communication systems related to the bow loading control station.

27.1.4.2 The following plans and documents are to be submitted for information:

(1) operation manual of bow loading systems.

27.1.4.3 For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by ISC.

Section 2 ARRANGEMENT

27.2.1 Arrangement of bow loading systems

27.2.1.1 Cargo lines used for bow loading are to be arranged outside accommodation spaces, service spaces, machinery spaces and control stations, and they are to be clearly identified.

27.2.1.2 The bow loading system is to be so arranged as not to interfere with the operation and use of life-saving appliances and embarkation stations at bow. The stowage position of life-saving appliances and embarkation stations are to have a distance of not less than 10 m from the coupling.

27.2.1.3 Enclosed spaces containing the working area of bow loading coupler are to be provided with mechanical ventilation system capable of giving at least 30 air changes per hour.

27.2.1.4 For oil tankers provided with emergency towing arrangements at bow, the bow loading system is

to be so designed as not to interfere with the operation and use of emergency towing arrangements.
27.2.1.5 The working area of bow loading coupler is to be provided with sufficient lighting that ensures good working environment.

27.2.2 Bow loading control station
27.2.2.1 For ships provided with bow loading systems, a control station for bow loading is to be arranged within the bow area or on the navigation bridge.
27.2.2.2 Where the bow loading control station is arranged within the bow area, positive pressure mechanical ventilation is to be provided.
27.2.2.3 Where the bow loading control station is arranged within the bow area, at least one lifejacket and one immersion suit are to be provided for each person on watch.

27.2.3 Classification of hazardous areas and electrical equipment in hazardous areas
27.2.3.1 For oil tankers provided with bow loading systems, classification of hazardous areas and electrical equipment in hazardous areas are, in addition to additional requirements for oil tankers in Section 16, Chapter 2, PART FOUR of the Rules, to comply with the provisions of this Section.
27.2.3.2 Where the cargo hose joint is arranged outside the cargo tank area, for the purpose of electrical equipment or ignition devices, areas within 3 m from the manifold are to be considered as hazardous area zone 1, with corresponding requirements to electrical equipment and wiring.
27.2.3.3 Spaces housing the loading pipe (fitted with detachable joint) and bow loading coupling are to be considered as hazardous area zone 1, with corresponding requirements to electrical equipment and wiring.
27.2.3.4 Entrances, air inlets and openings to service and machinery spaces and control stations are not to face the bow loading coupling, and are to be located at least 10 m from the bow loading coupling. Direct access from the hazardous bow loading coupler room to non-hazardous spaces in the forecastle area is acceptable provided protected from gas ingress as follows:
An air lock in accordance with IEC60092-502 is provided between the bow loading coupler room and an intermediate space. The air lock will be considered as a hazardous zone 2. The intermediate space complies with the requirements to an air lock in IEC60092-502. The intermediate space will be considered as a non-hazardous space.
27.2.3.5 Spaces considered as non-hazardous are not to have any connections with hazardous spaces or areas, and are to be ventilated in accordance with IEC60092-502.

Section 3 EQUIPMENT AND OUTFITS

27.3.1 Mooring equipment and its supporting structures
27.3.1.1 The ship is to be provided with suitable mooring equipment that can be used in conjunction with the ship's manoeuvring system to ensure that the ship is moored during bow loading. The mooring equipment is to be arranged to prevent the mooring load from being transferred to the oil pipeline used for loading.
27.3.1.2 Mooring equipment and its arrangement are to meet Oil Companies International Marine Forum (OCIMF) mooring equipment guidelines
27.3.1.3 The arrangement plan of mooring equipment is to indicate the safe working load of equipment.
27.3.1.4 The design load of the hull supporting structure of the mooring equipment is to be 2 times the safe working load of the equipment, and the calculated stress is not to exceed the minimum yield limit of the material used.

Section 4 PIPING SYSTEMS

27.4.1 General provisions
27.4.1.1 Materials, design and manufacture and testing of piping systems, valves and fittings of bow loading systems are to comply with applicable requirements of Chapter 2 of PART THREE of the Rules.
27.4.1.2 For ships to which this Chapter is applicable, requirements for bow loading in Chapter 5 of PART THREE of the Rules are replaced by requirements of this Chapter.

27.4.2 Cargo lines
27.4.2.1 Cargo lines used for the bow loading system which are outside the cargo area are to have welded

connections. Flanged connections may be used in way of the coupler. If necessary, expansion joints of flanged connection may be permitted when compensation is needed for lines subject to expansion and contraction.
27.4.2.2 Lines of the bow loading system and lines within the cargo area are to be effectively segregated in the cargo area by the following methods or equivalent means:
(1) a spool piece and blanking the line ends; or
(2) a valve and blanking the line ends; or
(3) two valves which can be secured in the closed position and provided that the efficiency of the segregation can be checked.
27.4.2.3 The bow loading coupling is to be fitted with a shut-off valve and a blank flange. The blank flange may be omitted when a patent hose coupling is fitted. A spill tray or coaming arrangement is to be provided in way of the bow loading coupling. Means for draining the spill tray to the cargo tank or slop tank are to be provided.
27.4.2.4 The cargo line is to be arranged to drain cargoes in the line to the cargo tank or slop tank by itself or by means of a draining device, where necessary by connection to a stripping device.
27.4.2.5 Spray shields are to be provided in way of valves or joints with potential leakage of the loading manifold of bow loading system except where the loading manifold is located outboard.
27.4.2.6 Means of inerting, purging and gas freeing for relevant lines of bow loading piping system are to be arranged, and the connected vent pipes are to be located in the cargo area. The relevant joints to the lines are to be fitted with shut-off valves and blank flanges.

Section 5 CONTROL AND MONITORING

27.5.1 General requirements

27.5.1.1 The control and monitoring of electrical installations are, in addition to the applicable requirements of the Rules, to comply with the provisions of this Section.
27.5.1.2 For instrumentation, equipment and automation, including computer based control and monitoring, the requirements of Chapter 2, PART SEVEN of the Rules are to be complied with.
27.5.1.3 From the control station for bow loading, all operations concerning positioning of the ship, operation and monitoring of bow loading safety systems, and monitoring of mooring and loading parameters are to be performed. The station is in general arranged on the navigation bridge and may also be arranged within the bow area Where the bow loading control station is arranged on the navigation bridge, it is to have concentrated arrangement and control and monitoring functions above. The bow area may also be provided with local operation which a necessary operation function of the bow loading system. Where the bow loading control station is only arranged within the bow area, all functions of the station are to be met.
27.5.1.4 Oil tankers applying for the notation DP are to satisfy the applicable requirements of Chapter 11 of this PART.

27.5.2 Instrumentation, equipment and automation

27.5.2.1 Ship manoeuvring instrumentation or equipment is to cover:
(1) thruster(s) control;
(2) main engine(s) emergency stop, or disengagement of clutch, if fitted;
(3) steering gear control, if fitted;
(4) radar;
(5) log.
27.5.2.2 Bow mooring instrumentation or equipment is to cover:
(1) mooring line traction control;
(2) chain stopper control;
(3) data logger system for recording of mooring and load parameters.
The mooring system is to be provided with a tension meter continuously indicating the tension during the bow loading operation. This requirement may be waived if the vessel has in operation an approved dynamic positioning system.
27.5.2.3 The bow loading system is to cover:
(1) indicator for loading connector coupling position;
(2) cargo valve position indicators;
(3) cargo tank level indicators and high level alarm (which may be omitted if the bow loading control station is located on the navigation bridge and such indicators are provided in other areas of the bridge);
(4) a system for automatic transfer of signals from the control and safety system, to enable automatic

termination of cargo supply from the offshore terminal;
(5) cargo pressure monitoring in the bow loading line in way of the bow loading coupling with high and low pressure alarms.
27.5.2.4 An emergency disconnection system is to be provided, which is to be activated from the control station.
- tripping the main crude oil transfer pumps;
- closing the connector and loading hose end coupler valves;
- start of the water sprinkler system;
- opening of the bow loading coupling claws;
- opening of the chain stopper.
In addition to the above automatic disconnection systems, a manually-operated backup emergency disconnection system is to be provided. Such a system may be based on accumulators providing hydraulic pressure.

27.5.3 Communication
27.5.3.1 Means of communication between the ship's cargo oil control station and bow loading control station and the offshore loading terminal are to be provided and certified safe for hazardous areas, if necessary.
27.5.3.2 Means of emergency communication between the bow loading control station and the offshore terminal are to be arranged.
27.5.3.3 Both primary and secondary methods are to be provided to ensure that continuous communication can be maintained between the bow loading control station and the offshore terminal in the event of any equipment failure or other problems arising during the operations.

Section 6 FIRE SAFETY

27.6.1 Fire protection, fire detection and fire extinction
27.6.1.1 Where the bow loading control station is arranged within the bow compartment, a protected escape route is to be provided and protected by a self-closing A-class door with the control station. The exit of the escape route is to be 10 m away from the coupling and not to face the joint of coupling.
27.6.1.2 Where the bow loading control station is arranged within the bow compartment, A-60 insulation protection is to be provided for boundaries adjacent to the space containing the coupling, including doors, windows and side scuttles.
27.6.1.3 At least one fire hydrant with associated fire hose and nozzle is to be provided in the working area of bow loading coupler.
27.6.1.4 The compartment containing the working area of bow loading coupler is to be provided with fixed combustible gas system and fire detection and alarm system. The alarm of the above systems is to be provided locally and in the bow loading control station.
27.6.1.5 The bow area is to be additionally provided with at least one additional foam monitor and one additional foam applicator complying with 2.2.2, Chapter 14 of the FSS Code, which are to be capable of effectively protecting the cargo lines and loading areas at bow.
27.6.1.6 Where the coupling and cargo lines are arranged in the compartment, a fixed foam fire-extinguishing system complying with the following requirements or other equivalent fire-extinguishing system is to be provided:
(1) foam sprinkler system. The system is to be capable of operating continuously for at least 30 minutes at a rate of not less than 6 L/m2 to protect the compartment; or
(2) fixed high-expansion foam system. The system is to be arranged to meet the requirements of the foam fire extinguishing system for the cargo pump room in Chapter 6 of the FSS Code.
The control of the fixed foam fire-extinguishing system required by this paragraph is to be located in an easily operable position outside the protected space.
27.6.1.7 The bow area is to be provided with a water spraying system with a spraying intensity not less than $5L/m^2$ per minute. The system is to cover potential spark generating equipment and location, e.g. mooring related equipment and coupling etc. The water spraying system is to be capable of being started within and outside the working area of bow loading coupler, and in addition, its control is to meet starting requirements in case of emergency disconnection.

Section 7 OPERATION MANUAL

27.7.1 Operation manual

27.7.1.1 An operation manual is to be provided on board, generally containing the bow loading operation procedure and safety measures that need to be taken during operation.

27.7.1.2 The operation manual is in general to give information regarding the following:

(1) Arrangement and equipment

① tank arrangement;

② arrangement and explanation of mooring equipment;

③ cargo loading and transfer system;

④ control station;

⑤ communication equipment;

⑥ other relevant equipment.

(2) Operation procedures

① communication procedure;

② mooring procedure;

③ connection and disconnection of cargo hose coupling;

④ transfer/distribution/storage of oil cargo;

⑤ oil spillage alarm of tanks.

(3) Safety measures

① emergency disconnection system;

② emergency communication system;

③ ventilation system;

④ fire safety system;

⑤ emergency escape routes.

(4) Cleaning and gas-freeing.

Section 8 TESTING AND SURVEY

27.8.1 Inspection and testing of products

27.8.1.1 Equipment forming the bow loading system is to be furnished with ISC certificates in accordance with the requirements of Chapter 3, PART ONE of the Rules.

27.8.1.2 Equipment forming the bow loading system is to be inspected and tested in accordance with approved plans and relevant standards.

27.8.2 Ship survey

27.8.2.1 For newbuildings and ships in service, the first survey after onboard installation is to comply with the provisions of 27.8.2.2 of this Chapter. The survey after construction is to comply with the provisions of 27.8.2.3 and 27.8.2.4 of this Chapter.

27.8.2.2 Initial classification survey

(1) checking the product certificate of equipment forming the bow loading system;

(2) checking the arrangement and installation of equipment forming the bow loading system comply with approved plans;

(3) After completion of installation, related equipment and systems of the bow loading system are subject to the following examination and testing:

① visual examination;

② examining and testing the function of instrument, automation and communication equipment in the bow loading control station (including the bow area and navigation bridge);

③ examining and testing the function of emergency disconnection system;

④ examining and testing the function of water spraying system;

⑤ interlock functional testing of mooring equipment and the bow loading system;

⑥ calibration testing of mooring line tension sensor;

⑦ functional test of the interconnection effect between the bow loading coupling and the connecting hose joint or equivalent device.

27.8.2.3 Annual survey

(1) The bow loading system is subject to the following examination:

① visual examination;

② examining and testing the function of instrument, automation and communication equipment in the bow loading control station (including the bow area and navigation bridge);

③ examining and testing the function of emergency disconnection system;

④ examining and testing the function of water spraying system.

27.8.2.4 The requirements for intermediate and special surveys are the same as those for annual survey.

Section 9 REQUIREMENTS FOR BOW LOADING SYSTEM*

27.9.1 General requirements

27.9.1.1 Oil tanks applying for Bow Loading System* may be exempted from the requirements of 27.5.2.3(4) of this Chapter, but are to comply with other requirements of this Chapter and the provisions of this Section.

27.9.2 System requirements

27.9.2.1 Reliable control and safety signal transmission are to be achieved between the bow loading system control station and offshore terminal. The offshore terminal is responsible for safe control of cargo oil supply.

27.9.2.2 The communication system required by 27.5.3 of this Chapter is to be capable of sending emergency signal in case of communication failure during the operation and timely terminate the operation.

27.9.2.3 The emergency disconnection system required by 27.5.2.4 of this Chapter can disconnect the main crude oil transfer pumps of the offshore terminal by means of 27.5.3 and 27.9.2.2 of this Chapter.

CHAPTER 28 ADDITIONAL REQUIREMENTS FOR CABLE LAYERS

Section 1 GENERAL PROVISIONS

28.1.1 Application

28.1.1.1 This Chapter applies to ships provided with cable laying machinery and other special equipment.

28.1.1.2 Cable layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of ISC Rules for Materials and Welding and of the flag State Administration, if any.

28.1.2 Notation

28.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Cable Layer.

28.1.3 Definition

28.1.3.1 Cable layers mean ships provided with cable laying machinery and other special equipment, engaged in under-sea cable laying for offshore wind plants, interconnection of power supply among islands and under-sea cable servicing.

28.1.4 Plans and documents

28.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to ISC for approval:

(1) Diagram for structural strengthening of cable laying equipment;

(2) Diagram for structural strengthening of positioning and towing equipment for cable laying operation;

28.1.4.2 The following plans and documents are to be submitted to ISC for information:

(1) Installation and arrangement of cable laying equipment;

(2) Strength calculations for structural strengthened cable laying equipment;

(3) Strength calculations for holds in cable capstan areas;

(4) Arrangement of positioning and towing equipment for cable laying operation;

(5) Strength calculations for structural strengthened positioning and towing equipment for cable laying operation.

For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by ISC.

Section 2 HULL STRUCTURE AND ARRANGEMENT

28.2.1 Hull structure

28.2.1.1 Hull structural strength is normally to comply with the requirements of main class rules, with consideration of the necessary reinforcement of the support structure of the equipment used in cable laying operation. For special hull structures, hull structural strength will be specially considered.

28.2.2 Cable capstan

28.2.2.1 Structural strength of holds in cable capstan areas is to be checked by means of direct assessment. For the checking methods, reference may be made to the Appendix “Method of Checking Transverse Strength of Pontoon Barges” of Chapter 12 of PART TWO of the Rules. During the check, the maximum bearing load of cable capstan is taken as the deck load in the cable laying area, which is applied on the deck according to the actual force forms.

28.2.3 Cable laying equipment

28.2.3.1 Strength of the strengthened structures of the cable laying equipment, and of the positioning and towing equipment during cable laying operation is to be checked in accordance of Sections 6 and 7 of Chapter 3 of PART TWO of the Rules.

28.2.4 Hold arrangement

28.2.4.1 The bunker cannot be directly positioned under the working deck, unless a void hold, storage hold or ballast tank is arranged between the working deck and the bunker. The working deck is to be distant from the engine room air inlet and outlet as far as possible. The obstacles in way of the hold vents are to be minimized.

CHAPTER 29 ADDITIONAL REQUIREMENTS FOR PIPE LAYERS

Section 1 GENERAL PROVISIONS

29.1.1 Application

29.1.1.1 This Chapter applies to ships provided with special equipment for laying pipes.

29.1.1.2 Pipe layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of ISC Rules for Materials and Welding and of the flag State Administration, if any.

29.1.2 Notation

29.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Pipe Layer.

29.1.3 Definition

29.1.3.1 Pipe layers mean ships provided with special equipment for laying pipes under sea.

29.1.4 Plans and documents

29.1.4.1 In addition to the plans and documents required in the relevant PARTs and Chapters of the Rules, the documents in relation to the pipe laying equipment (e.g. tensioners, A/R winches and stingers) are to be submitted to ISC for approval. For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by ISC.

Section 2 HULL STRUCTURE AND ARRANGEMENT

29.2.1 Hull structure

29.2.1.1 Hull structural strength is normally to comply with the requirements of main class rules, with consideration of the necessary reinforcement of the support structure of the equipment used in pipe laying operation. For special hull structures, hull structural strength will be specially considered.

29.2.2 Bunker

29.2.2.1 The bunker cannot be directly positioned under the working deck, unless a void hold or ballast tank is arranged between the working deck and the bunker.

29.2.3 Hold arrangement

29.2.3.1 The working deck is to be distant from the engine room air inlet and outlet as far as possible. The obstacles in way of the hold vents are to be minimized.

Section 3 EQUIPMENT

29.3.1 General provisions

29.3.1.1 Pipe layers are to be capable of anchor mooring positioning or dynamic positioning.

29.3.2 Wheel house

29.3.2.1 A pipe layer is to be provided with a wheel house with good vision, and communication by means of hardwired connection between the wheel house and the remote control station is to be provided.

CHAPTER 30 ADDITIONAL PROVISIONS ON THE FUNCTIONALITY OF RO-RO PASSENGER SHIPS

Section 1 GENERAL PROVISIONS

30.1.1 Application

30.1.1.1 This Chapter applies to ro-ro passenger ships applying for the notation specified in 30.1.2.

30.1.2 Notation

30.1.2.1 Upon application, ro-ro passenger ships complying with the relevant requirements of this Chapter may be assigned the notation: PVSED (Passenger and Vehicle Separated Embarkation and Disembarkation).

30.1.3 Definition

30.1.3.1 Variable lane, means an arrangement in which both big vehicle lane and small vehicle lane are marked in the same area, and the use of big vehicle lane or small vehicle lane is decided according to the vehicle condition of each voyage.

30.1.4 Plans and documents

30.1.4.1 In addition to those required in relevant Parts and Chapters of the Rules, the following plans and documents are to be submitted:

(1) Passenger and Vehicle Embarkation and Disembarkation Arrangement (approved);

Section 2 PASSENGER AND VEHICLE EMBARKATION AND DISEMBARKATION ARRANGEMENT

30.2.1 Passenger and vehicle separated embarkation and disembarkation arrangement

30.2.1.1 The ship is to be provided with embarkation and disembarkation access and entrance and exit dedicated to passengers.

30.2.1.2 The ship is to be provided with ramps for embarkation and disembarkation of vehicles.

30.2.1.3 Ro-ro spaces or special category spaces is to be provided with access for drivers to go directly to passenger spaces, and clear width of access is not to be less than 700 mm, in which the inclination angle of stairway is not to be greater than 50°. If the access is used as an escape route, it is also to meet the relevant requirements of the Administration of the flag State.

30.2.1.4 If passengers can only embark on and disembark from the ship through the vehicle ramp due to the limited terminal facilities, clear width of the passenger access is not to be less than 900 mm, and means of isolation that are not easy to be surmounted are to be provided on both sides of the access. Dedicated personnel are to guide passengers and vehicles and maintain order during embarkation and disembarkation. This measure is to be included in the safety management documents on board.

30.2.2 Vehicle deck

30.2.2.1 Upper and lower vehicle decks are to be connected by fixed or movable ramps.

30.2.2.2 Where terminal facilities are provided with multi-tier vehicle and/or passenger separated access, on-board vehicle and/or passenger decks are also to be provided with docking facilities with corresponding access of the terminal(if applicable).

30.2.3 Lane arrangement

30.2.3.1 Dedicated lanes in ro-ro spaces or special category spaces are to be clearly marked.

30.2.3.2 The arrangement of variable lanes is acceptable.

30.2.3.3 Where big vehicle and small vehicle dedicated lanes are arranged in vehicle decks or some areas, such lanes are to be clearly marked with different colors and lines.

30.2.4 Lane width

30.2.4.1 Width of small vehicle lanes is not to be less than 2.4 m, and width of big vehicle lanes is not to be less than 3 m.

CHAPTER 31 NOTATIONS FOR OTHER EQUIPMENT

Section 1 GENERAL PROVISIONS

31.1.1 General requirements

31.1.1.1 The provisions of this Chapter are voluntary and optional, which apply to ships with various special equipment.

Section 2 NOTATION FOR VIDEO MONITORING SYSTEM

31.2.1 Notation

31.2.1.1 Upon application, a ship provided with equipment complying with the requirements of this Section may be assigned the following notation: VDMS (video monitoring system).

31.2.2 Definitions

31.2.2.1 For the purpose of this Section, the following definitions apply:

(1) Video detection means a kind of detection method to perceive the object by photoelectric imaging technology (from near-infrared to the limit of visible spectrum) and to form video picture signals.

(2) Video monitoring means to monitor the object by adopting with video method and to record object information.

(3) Video transport means or from one equipment to another one directly or through modulation demodulation by adopting with the wire or wireless transmission medium.

(4) Video switcher means the video controller, which is the core device of the operation and controlling of the video system and generally is able to complete the video switching and the controlling of cradle head and lens, etc.

(5) Front-end device means all kinds of equipment distributed on the detection site. In this system, it usually refers to the video camera as well as its relevant matching devices (such as lens, cradle head, decoding driver, shield, etc.).

(6) Video motion alarm means a means of alarm that uses video detection technology to detect changes in scene images and sends out alarm information once the set threshold is reached.

(7) Video signal loss alarm means a system function, i.e. when the video switcher monitors the video signal from the front end, once the peak value of the video signal is less than the set value, the system will consider the video signal loss and provide alarm information.

31.2.3 Plans and documents

31.2.3.1 The following plans are to be submitted for approval:

(1) Electrical system diagram of video monitoring system;

(2) Electrical equipment arrangement plan of video monitoring system.

31.2.4 General requirements

31.2.4.1 Ship video monitoring system is generally composed of four main parts, i.e. front-end device, transport device, control and record display device.

31.2.4.2 The front-end device can be divided into separate combined camera or integrated camera.

31.2.4.3 Control and record display device can be separated or integrated.

31.2.5 Video detection front-end device

31.2.5.1 Video detection front-end device is to be able to clearly and effectively detect and identify pictures of important locations, covering areas such as navigation bridge, engine room, public spaces, corridors and stairways (passenger ship), special category and ro-ro spaces, fire control stations, etc.

31.2.5.2 Video detection front-end device is to be able to adapt to the lighting conditions of the site. When the illumination of the site cannot meet the requirements for clear detection, the equipment is to be provided with night vision function or auxiliary lighting equipment.

31.2.5.3 The enclosure protection grade and certified safe type (if applicable) of the video detection front-end device is to be appropriate to the space where it is installed.

31.2.6 Video monitoring system

31.2.6.1 The video monitoring system is to have automatic storage function, not causing loss of stored data in case of power off or shutdown.

31.2.6.2 The video monitoring system for ro-ro spaces is to monitor the front-end video signal and give a video motion alarm.

31.2.6.3 The video monitoring system is to give a video signal loss alarm at the display terminals, and this alarm is auditory and visual.

31.2.6.4 The video monitoring system is to be able to store monitoring records for at least 30 days.

31.2.6.5 The video monitoring system is to have ports for networking and remote operation and invocation.

Section 3 NOTATION FOR NIGHT VISION EQUIPMENT

31.3.1 Notation

31.3.1.1 Upon application, a ship provided with equipment complying with the requirements of this Section may be assigned the following notation: NVE (night vision equipment).

31.3.2 Definition

31.3.2.1 For the purpose of this Section:

(1) Night vision equipment means any technical means enabling the position and aspect of objects above the water surface relative to the ship to be detected at night.

31.3.3 Plans and documents

31.3.3.1 The following plans and documents are to be submitted for approval:

(1) Electrical system diagram of night vision equipment;

(2) Electrical equipment arrangement plan of night vision equipment.

31.3.4 General requirements

31.3.4.1 Night vision equipment① facilitates the detection at night of hazards to navigation above the water surface, thus providing essential information to the navigator for collision avoidance and safe navigation.

31.3.5 Technical requirements

31.3.5.1 Night vision equipment is to be capable of detecting objects within a certain distance from the ship, and of displaying the information pictorially in real time, to assist in collision avoidance and safe navigation.

31.3.5.2 Night vision equipment is to be operational in less than 15 min after the equipment has been switched on, and is to be capable of continuous operation from after sunset until before sunrise.

31.3.5.3 The controls of night vision equipment are to be installed in the work area for navigating and manoeuvring, within easy reach of the navigator. For any failure of the night vision equipment, a visual indication is to be provided on the navigation bridge.

31.3.5.4 The operational controls of night vision equipment are to be clearly identifiable in the dark. If illumination is used, the brightness is to be adjustable.

Section 4 NOTATION FOR FOG NAVIGATION ENHANCED SENSING

31.4.1 Notation

31.4.1.1 Upon application, a ship provided with equipment complying with the requirements of this Section may be assigned the following notation: EFN-M (fog navigation enhanced sensing system - manual identification) and EFN-A (fog navigation enhanced sensing system - intelligent identification).

31.4.2 Definitions

---

① Refer to Annex of resolution MSC.94(72) Recommendation on Performance Standards for Night Vision Equipment for High Speed Craft (HSC).

31.4.2.1 For the purpose of this Section:
(1) Typical target identification means the cognition of target characteristics of ships, buoys, shorelines, islands, reefs, etc. Target characteristics are to at least include target position, speed, heading, category, encounter distance, encounter time, movement trend, etc.
(2) Visual fog penetration means the use of optical fog penetration, software fog penetration, thermal imaging and other technologies to detect and identify typical targets in the navigation environment. These targets are visually displayed on the display unit, and the navigator or intelligent system can effectively identify typical targets.
(3) Image identification function means identification using computer programs or algorithms based on the image or thermal imaging of typical targets, by means of of machine learning and other artificial intelligence technologies.
(4) Data fusion function means the automatic fusion of visual fog penetration data and traditional navigation sensing data through computer programs or algorithms for comprehensive identification of typical targets, such as radar echo of collision-avoiding targets, automatic identification instrument, and superposition of image data.
(5) Cradle head means the supporting equipment installed with fog penetration sensor to provide stability function and ensure the stability of target detection during ship navigation.
(6) Fog penetration sensor means the camera or heat source probe with fog penetration function.
(7) Control and data processing unit means the control, data collection, storage and processing of visual fog penetration equipment based on computer technology, which can access the data of traditional navigation sensing equipment, realize image identification and data fusion, continuously detect the operational state of the equipment, and provide man-machine operation interface.
(8) Fault alarm means the alarm information given when the performance of fog navigation enhanced sensing system is significantly reduced or fails.
(9) Traditional navigation sensing equipment means the detection equipment for navigation environment and collision-avoiding targets provided according to the requirements of the existing conventions and rules, such as radar, electronic chart display and information system, automatic identification instrument, etc.
(10) Intelligent identification means identification of the fused data of typical targets by use of artificial intelligence technology or automation technology.
(11) Visibility means the maximum horizontal distance a person with normal vision can see the outline of a target clearly in prevailing weather conditions.

31.4.3 Plans and documents

31.4.3.1 The following plans and documents are to be submitted for approval:
(1) Electrical system diagram of fog navigation enhanced sensing system;
(2) Electrical equipment arrangement plan of fog navigation enhanced sensing system.

31.4.4 General requirements

31.4.4.1 Fog navigation enhanced sensing system is based on optical fog penetration, software fog penetration, thermal imaging, image identification and other technologies. By filtering the impact of haze and fog, smoke and soot, rain and snow on vision, it identifies collision-avoiding targets and reduces collision risk.
31.4.4.2 Fog navigation enhanced sensing system can effectively make up for the defect of navigator's vision in the fog condition, i.e. not being able to effectively find collision-avoiding targets at a long distance.
31.4.4.3 Visual fog penetration equipment is composed of fog penetration sensor, control and data processing unit and display unit.
31.4.4.4 Fog navigation enhanced sensing system is composed of traditional navigation sensing equipment and visual fog penetration equipment, realizing one of the following two functions.
(1) The navigator integrates the data of two types of equipment to manually identify typical targets, i.e., EFN-M;
(2) On the basis of (1), the system can carry out image identification and display for typical targets, and carry out intelligent identification for fusion data of typical targets, i.e., EFN-A.

31.4.5 Technical requirements

31.4.5.1 The fog navigation enhanced sensing system is to have video fog penetration function as a minimum, and the following advanced functions may also be provided:
(1) image identification function;
(2) data fusion function.

31.4.5.2 Video fog penetration can be realized by one or more fog penetration technologies such as optical fog penetration, software fog penetration and thermal imaging.
31.4.5.3 The application environment of fog navigation enhanced sensing system is haze and fog, smoke and soot, rain and snow as well as other typical marine environment.
31.4.5.4 The camera of video fog penetration is to have optical zoom function.
31.4.5.5 The effective distance of the fog navigation enhanced sensing system is to be not less than 1 nautical mile, including at night.
31.4.5.6 The fog penetration sensor can rotate at least 180°in the horizontal direction and is to be adjustable; the maximum horizontal rotation speed is above 20°/S and adjustable; the detection range in the vertical direction is to be at least +60~-60° and adjustable; the maximum vertical rotation speed is above 20°/S and adjustable. The fog navigation enhanced sensing system shall be able to operate normally in the visibility of 0.28 nautical mile to 0.55 nautical miles, and the operating distance shall be greater than 1 nautical mile, including the dark environment.
31.4.5.7 Video fog penetration camera is to have not less than 2 million pixels. The resolution of the thermal sensor is not to be less than 320×240.
31.4.5.8 On the basis of visual fog penetration, the image identification function can in general automatically identify typical targets such as ships, buoys, shorelines, islands and reefs.
31.4.5.9 The data fusion function needs to fuse the following data, and achieve the artificial identification by navigator or intelligent identification by system of typical targets:
(1) automatic identification instrument data;
(2) electronic chart data;
(3) information of other ships, such as position, heading, speed and encounter distance;
(4) information of other obstacles, such as position, relative direction, relative speed;
(5) navigation radar data;
(6) data of visual fog penetration equipment.
31.4.5.10 The fog navigation enhanced sensing system is to meet the following design principles of bridge equipment:
(1) assisting bridge staff and pilots to perform navigation tasks;
(2) promoting effective and safe management of bridge resources;
(3) enabling bridge staff and pilots to conveniently and continuously obtain important information;
(4) indicating the working state of fog navigation enhanced sensing system;
(5) enabling bridge staff and pilots to process information and make decisions quickly, continuously and effectively;
(6) preventing or minimizing unnecessary work in the bridge that may lead to fatigue of staff and pilots, decreased vigilance and other factors, such as distractive affairs;
(7) identifying and reducing the risk of human error to the maximum extent through monitoring and alarm system, so that bridge staff and pilots can take corresponding actions in a timely manner;
(8) effective maintenance, such as maintenance manual, maintenance plan, etc.
31.4.5.11 The fog navigation enhanced sensing system is to have the functions of self-inspection and alarm, and can provide continuous monitoring during normal operation of the equipment.
When the equipment performance is significantly reduced or failure is detected, the system is to be able to send prompt alarm and fault information.
31.4.5.12 The fog navigation enhanced sensing system shall have an interface connected to the ship voyage recorder.

CHAPTER 32 TRANSVERSE PROPULSION ARRANGEMENT

Section 1 GENERAL PROVISIONS

32.1.1 Application

32.1.1.1 This Chapter applies to ships provided with transverse propulsion arrangement and applying for the T-Propulsion notation.

32.1.1.2 Certification requirements and inspections of products with regard to transverse propulsion arrangement are to comply with relevant provisions of Chapter 3, PART ONE of the Rules.

32.1.2 Notation

32.1.2.1 Ships provided with transverse propulsion arrangement complying with the provisions of this Chapter may be assigned the notation: T-Propulsion.

32.1.3 Definition

32.1.3.1 Transverse propulsion arrangement is a special propelling unit fitted in the transverse duct below the waterline at the ship's bow or stern.

32.1.4 Plans and documents

32.1.4.1 The following plans and documents are to be submitted for approval or information:

(1) arrangement plan of transverse propulsion arrangement (for information);

(2) plan of piping system of hydraulic system (where fitted);

(3) plan of piping system of lubricating oil (where fitted);

(4) plan of electrical system of transverse propulsion arrangement;

(5) list of control, monitoring and alarm.

Section 2 TRANSVERSE PROPULSION ARRANGEMENT

32.2.1 General requirements

32.2.1.1 Transverse propulsion arrangement is to have sufficient transverse thrust to satisfy the working requirements of navigation at low speed and docking and leaving wharf.

32.2.1.2 Material and test of transverse propulsion arrangement and its components are to comply with the relevant requirements of ISC Rules for Materials and Welding.

32.2.1.3 Diesel engines driving transverse propulsion arrangement are to comply with the relevant requirements in Chapter 9, PART THREE of the Rules.

32.2.1.4 Motor and distribution system of driving transverse propulsion arrangement are to comply with the relevant requirements in PART FOUR of the Rules.

32.2.1.5 The design of shafting together with its parts and propeller is to comply with the relevant requirements of Chapter 11, PART THREE of the Rules.

32.2.1.6 The thickness of tunnel of transverse propulsion arrangement is not to be less than the adjacent part of the hull.

32.2.1.7 The shaft sealing box is to be installed to prevent water so as to protect steel shafts from sea water.

32.2.1.8 For installed corrosion prevention of cylinders, means of cathodic protection or corrosion prevention materials are to be provided.

32.2.2 Hydraulic transmission piping system (where fitted)

32.2.2.1 After being assembled as a set, the pipe lines and pressure elements of hydraulic transmission system and control system for controllable pitch propellers are to be subject to tightness test to a pressure of 1.25 times the design pressure. There is to be no leakage in way of permanent sealing and pipe joints.

32.2.2.2 Materials, piping systems and arrangement of hydraulic transmission piping system are to comply with applicable requirements of Section 7, Chapter 4, PART THREE of the Rules.

32.2.3 Lubricating oil piping system (where fitted)

32.2.3.1 Lubricating oil system and tank arrangement are to comply with applicable requirements of

Chapters 3 and 4, PART THREE of the Rules.

Section 3 CONTROL, MONITORING AND ALARM

32.3.1 General requirements

32.3.1.1 Control, monitoring and alarm of the transverse propulsion arrangement are, in addition to requirements of this Chapter, to comply with relevant requirements of PART SEVEN of the Rules.

32.3.1.2 It is to be possible to stop the transverse propulsion arrangement from the bridge by means of a system independent of the remote control system.

32.3.1.3 The transverse propulsion arrangement is to be provided with indications, individual or groupwise alarms specified in Table 32.3.1.3.

Alarm and monitoring **Table 32.3.1.3**

Item	Indication	Alarm
Overload of prime mover and servo unit		X
Power failure of remote control system		X
Power failure of alarm system		X
Level in lubrication oil tank (if fitted)		Low
Lubrication oil pressure (if forced lubrication oil system)		Low
Level in hydraulic daily service tank (where applicable)		Low
Pressure in hydraulic system		Low
Running and stop of prime mover	X	
Propeller pitch for controllable pitch propeller plants	Propeller pitch	
Direction of rotation for fixed propeller plants;	Direction of rotation	
r.p.m. for fixed propeller plants	r.p.m.	

32.3.1.4 Where the ship applies for the dynamic positioning notation at the same time, the transverse propulsion arrangement is to be provided with alarms and indications complying with Chapter 11, PART EIGHT of the Rules in the dynamic positioning control station.

CHAPTER 33 SHIP COMMUNICATION NETWORKS SATISFYING SPECIFIC NEEDS

Section 1 GENERAL PROVISIONS

33.1.1 General requirements

33.1.1.1 The provisions of this Chapter apply to ships of which the communication networks satisfy specific needs.

33.1.1.2 The specific needs mentioned in this Chapter refer to communication needs such as passenger using Internet and remote survey.

33.1.1.3 The ship communication networks mentioned in this Chapter refer to the communication networks which realize the specific needs in 33.1.1.2 through ship communication network equipment, based on hosting modes of communication networks such as satellite broadband communication network and 4G or 5G cellular communication network.

33.2.1.4 The applicant is to be responsible for whether the operator of the ship communication network services meets the requirements of relevant laws and regulations.

33.2.1.5 The applicant is to ensure that the management and operation of the ship communication network meet the requirements of relevant laws and regulations, such as real-name registration for network users.

33.1.2 Class notations

33.1.2.1 Upon its application, a ship the ship communication network of which has undergone plan approval and survey by ISC and satisfied the relevant requirements of this Chapter, may be assigned class notations as follows:

Specific Communication Network (Px, Rx)

where the letters P and R in the parentheses stand for the specific needs of the ship communication network, which may be assigned according to the actual function of the ship and are defined as follows:

P - network provided for passengers to satisfy the daily communication needs of passengers to use the Internet.

R - network provided for crew to satisfy the communication needs for ship remote survey.

x - additional notations for hosting modes of ship communication networks. Each small letter indicates one hosting mode. The ship communication network satisfying one specific need may be realized by one or more hosting modes, which may be assigned one or more additional notations where:

s - ship communication network realized by satellite broadband communication network.

c - ship communication network realized by 4G or 5G cellular communication network.

If the ship realizes the needs for daily use of the Internet by passengers and ship remote survey in accordance with the requirements of this Chapter, based on satellite broadband communication network and 4G or 5G cellular communication network respectively, it may be assigned Specific Communication Network (Ps, Pc, Rs, Rc).

Section 2 TECHNICAL REQUIREMENTS

33.2.1 Hosting modes

33.2.1.1 The hosting modes of ship communication networks may be satellite broadband communication network, 4G or 5G cellular communication network, etc.

33.2.2 Network bandwidth

33.2.2.1 The communication network bandwidth is to satisfy the actual needs through the estimation of communication traffic and network capacity load test.

33.2.2.2 For ships applying for class notation "Ps", the theoretical bandwidth of the communication network is not to be less than 2 Mbps for upstream rate and 4 Mbps for downstream rate, which is to be confirmed by relevant supporting documents provided by the ship communication network service provider. The measured bandwidth is not to be less than 1 Mbps for upstream momentary rate and 2 Mbps for downstream momentary rate. For ships applying for class notation "Pc", the measured bandwidth is not to be less than 5 Mbps for upstream momentary rate and 25 Mbps for downstream momentary rate.

33.2.2.3 For ships applying for class notation "Rs", the theoretical bandwidth of communication network is not to be less than 2 Mbps for upstream rate and 2 Mbps for downstream rate, which is to be confirmed by relevant supporting documents provided by the ship communication network service provider. The measured bandwidth is not to be less than 1 Mbps for upstream momentary rate and 1 Mbps for downstream momentary rate. For ships applying for class notation "Rc", the measured bandwidth is not to be less than 4 Mbps for upstream momentary rate and 4 Mbps for downstream momentary rate.

33.2.3 Equipment arrangements

33.2.3.1 Local area network (LAN) is to be arranged to realize the network coverage of relevant spaces.

33.2.3.2 For ships applying for class notation “P”, the network is to be arranged by fixed LAN devices. The network is to cover the living areas of passengers, including primary accommodation spaces as a minimum, such as public spaces, corridors, cabins, cinemas, game and hobby rooms.

33.2.3.3 For ships applying for class notation “R”, the network may be arranged by fixed LAN devices and/or portable network relay equipment which are readily deployed. The network is to cover the survey areas of remote survey including spaces falling in the scope of annual survey as a minimum, such as engine room, steering gear room, other machinery spaces, accommodation spaces, service spaces, control station, forecastle and cargo area (where applicable).

33.2.4 Equipment requirements

33.2.4.1 The ship communication network is to be isolated from the networks related to the normal operation and safety of the ship, such as navigation equipment network, machinery control system network, alarm system network, etc.

33.2.4.2 Ship communication network equipment, which generally contains receiving unit, signal amplification unit, hub, switch, network bridge, router, gateway, network access point, modem, portable network equipment (including customer terminal equipment (CPE), network relay equipment), etc., is to meet the relevant requirements of Sections 2 and 3, Chapter 1, PART FOUR of the Rules.

33.2.4.3 The cables provided for the ship communication network equipment are to meet the relevant requirements of Section 12, Chapter 2, PART FOUR of the Rules.

33.2.4.4 The ship communication network equipment may be powered by main source of electrical power. For ships applying for class notation "R", there is to be a standby power to supply the network for not less than 0.5 hours (for portable equipment, not less than 4 hours), such as UPS or accumulator batteries, etc.

33.2.4.5 Manufacture’s supporting documents of the ship communication network equipment are to be provided for check. System and equipment installed in places with explosion risk are to be explosion-proof, or corresponding measures are to be taken to avoid explosion risks during use at least.

33.2.4.6 The construction, operation, maintenance and security assessment of the ship communication network system and equipment may be implemented with reference to the relevant requirements in ISC Guidelines for Requirement and Security Assessment of Ship Cyber System.

33.2.4.7 The procedures for daily inspection and maintenance of the ship communication network equipment are to be implemented onboard, including inspection for equipment working status and power supply status, connection identifier for cables, network connectivity, etc., and the results are to be recorded.

Section 3 PLANS AND DOCUMENTS

33.3.1 Plans and documents

33.3.1.1 The following plans and documents are to be submitted to ISC for approval:

(1) Arrangement of ship communication network equipment;

(2) Power supply plan of ship communication network equipment.

33.3.1.2 The following plans and documents are to be submitted to ISC for information:

(1) Topology diagram of ship communication network system;

(2) Estimation of communication traffic for ship communication network;

(3) Specification of cables for ship communication network equipment;

(4) Specification of working conditions for ship communication network equipment;

(5) List of ship communication network equipment, including brand, model, quantity and function description as a minimum;

(6) Operation manual of ship communication network equipment.

33.3.1.3 The following plans and documents are to be submitted to ISC surveyor for approval and/or confirmation:

(1) Test program including test procedures, acceptance criteria and records of test results;

(2) Procedures for daily inspection and maintenance of ship communication network equipment.

Section 4 SURVEY AND TESTS

33.4.1 Initial surveys

33.4.1.1 The surveyor is to confirm the actual installation layout of the ship communication network equipment onboard according to the reviewed plans and documents, and confirm the function and working status of the communication network equipment according to the approved test program. Where necessary, the surveyor is to review the relevant documents provided by the service provider required in 33.2.2.

33.4.1.2 The test for ship communication network is to be carried out under the witness of the surveyor according to the test program, including:

(1) The connectivity test of system and equipment;

(2) The network coverage test: for the network coverage spaces indicated in the plan referred to in 33.3.1.1 (1), at least one representative network access point is to be selected for each space for test;

(3) Communication network capacity load test, bandwidth test, network transmission delay test and network stability test, which are to be carried out simultaneously with the test referred to in 33.4.1.2 (2);

(4) The functional tests of the communication network, such as real-time video communication, document transmission, etc., which are to be carried out simultaneously with the test referred to 33.4.1.2 (2).

33.4.2 Annual surveys

33.4.2.1 After assigned with the class notation specified in this Chapter, as the condition of maintenance of the notation, the following survey is to be carried out during the subsequent class periodical survey:

(1) Relevant plans and documents are to be kept onboard, and no unconfirmed changes by ISC have been made;

(2) The system and equipment are in normal working condition, and no unconfirmed changes by ISC which affect the realization of specific needs specified in this Chapter have been made;

(3) Records for relevant daily inspection and maintenance are checked;

(4) If necessary, some or all tests may be carried out according to 33.4.1.

33.4.3 Intermediate surveys

(1) The requirements for intermediate surveys are the same as those for annual surveys.

33.4.4 Special surveys

(1) The requirements for special surveys are the same as those for annual surveys.

33.4.5 Occasional surveys

33.4.5.1 In case of any change, fault or damage to the approved plans and documents, systems and equipment, which affect the realization of specific needs of the communication network specified in this Chapter, ISC is to be notified in time for occasional surveys to maintain the validity of the class notation.

33.4.6 Maintenance, cancellation and withdrawal of the class notation

33.4.6.1 The ship is to meet the requirements of this Chapter to maintain the validity of the class notation. Otherwise, ISC will cancel the relevant class notation as appropriate.

33.4.6.2 The ship company can apply for cancellation of the relevant class notation specified in this Chapter in written form.

CHAPTER 34 EVALUATION OF COLLISION RESISTANCE CAPABILITY OF SHIPS

Section 1 GENERAL PROVISIONS

34.1.1 General requirements

34.1.1.1 This Chapter applies to ships applying for the class notation related to evaluation of collision resistance capability on a voluntary basis.

34.1.1.2 Ships applying for evaluation of collision resistance capability generally are subject to, but not limited to the following three critical situations:

(1) Structural damage to cargo tanks with subsequent leakage of, e.g., oil, chemicals, etc.;

(2) Structural damage leading to water ingress into dry cargo holds during carriage of particularly valuable or dangerous cargo;

(3) Structural damage to fuel oil tanks with subsequent leakage of fuel oil.

34.1.1.3 Evaluation of collision resistance capability of ships is intended to calculate the deformation energy absorbed by the hull structure and critical striking speed of striking ships of different magnitude that the hull structure can bear when the ship structure is struck by another ship and the hull structure shell plate (inner hull plate for a double hull ship) is in the critical damaged state, and to give the displacement – critical striking speed curve of the struck ship, so as to guide the operation of the ship.

34.1.1.4 The simplified method or FE method may be used for evaluation of collision resistance capability. For the FE method, the general FE analysis procedure may be used. If non-general procedures are used, the explanatory documents on the reliability of the calculation procedures are to be provided by the unit applying for the notation.

34.1.2 Definitions

34.1.2.1 The **critical damaged state** refers to the state when the maximum plastic deformation of the hull structure shell plate (inner hull plate for a double hull ship) of the struck ship occurs without rupture.

34.1.2.2 The **initial striking speed** V_0, in knots, refers to the speed of the striking ship when striking occurs.

34.1.2.3 The **critical striking speed** V_{cr}, in knots, refers to the maximum striking speed that the struck ship can bear in the critical situation. If the speed of the striking ship exceeds this value, the expected critical state will occur.

34.1.2.4 The **critical deformation energy** E_{cr}, in MJ, refers to the plastic deformation energy absorbed by the hull structure when large plastic deformation occurs in the hull structure shell plate (inner hull plate for a double hull ship) of the struck ship without rupture in case of a collision. When that amount of energy is exceeded, the expected critical state will occur.

34.1.3 Class notation

34.1.3.1 Ships that have undergone evaluation of collision resistance capability according to the requirements of this Chapter may be assigned with the notation “COLL”.

34.1.4 Plans and documents

34.1.4.1 The following plans and documents are to be submitted for approval in addition to the plans and documents required by relevant chapters and PARTS of the Rules:

(1) Critical striking speed curve.

34.1.4.2 The following plans and documents are to be submitted for information:

(1) Strength analysis report, including structural collision deformation energy analysis and critical speed analysis.

(2) List of critical situations in which the ship is involved.

34.1.5 Document retention

34.1.5.1 The shipowner is to keep the plans and documents required by 34.1.4.1 onboard the ship and make them accessible to the operator in case of a collision.

Section 2 EVALUATION METHODS

34.2.1 Evaluation conditions

34.2.1.1 The bow of the striking ship meets the side of the struck ship at 90°, and the struck ship has no speed and remains upright.

34.2.1.2 The impact area is to be taken as the side structure between the two transverse bulkheads of the cargo hold area within 0.4*L* amidships.

34.2.1.3 The location of collision is to be the most dangerous collision point selected according to the relative draft of the striking ship and the struck ship.

34.2.1.4 The most dangerous bulbous bow form is to be selected according to the ship type and displacement, and the structure is assumed to be rigid.

34.2.2 Critical deformation energy of the side structure

34.2.2.1 The Minorsky method or a validated analytical method may be accepted to calculate critical deformation energy of the side structure. Assuming that the structural response is quasi-static and the material is ideal elastic plastic, the structural plastic deformation energy is calculated when the side structure in the impact area of the struck ship is damaged to the critical state.

34.2.2.2 When the FE method is adopted, the dynamic response of the structure is to be calculated. The bow of the striking ship ramming into the struck ship at the initial striking velocity V_0, and the kinetic energy loss of the striking ship is all transformed into the kinetic energy of the struck ship and the plastic deformation energy absorbed by the structure, until the critical damaged state of the side structure is reached. For the impact on the attached water mass of the ship, the total mass of the striking ship is to be 1.1 times its own displacement, and the total mass of the struck ship is to be 2 times its own displacement.

34.2.3 Critical striking speed of the ship

34.2.3.1 The critical striking speed V_{cr} of the ship is to be calculated according to the following formula:

$$V_{cr} = 19.41\left\{\frac{10E_{cr}}{\Delta}\left(1 + 1.815\frac{\Delta}{\Delta_0}\right)\right\}^{0.5} \quad \text{kn}$$

where: Δ——displacement of the striking ship, in t;

Δ_0——displacement of the struck ship, in t;

E_{cr}——critical deformation energy of the struck ship, in MJ, see 34.2.2 of this Chapter.

Section 3 EVALUATION CRITERIA

34.3.1 Evaluation criteria collision resistance capability

34.3.1.1 Ships of approximately equal displacement and with design draughts approximately identical to that of the struck ship to be examined are to be assumed as striking ships. The critical striking speed, V_{cr}, of the ship is not to be less than 7 kn.

Section 4 CRITICAL STRIKING SPEED CURVE

34.4.1 Critical striking speed curve

34.4.1.1 According to the analysis results of collision of ships with different levels of displacement, the relationship curve between the critical striking speed and the displacement of the striking ship is drawn to provide guidance for navigation operation.

34.4.1.2 The range of the struck ship displacement required to draw the critical striking speed curve is to include but not be limited to 0.5~1.5 times the striking ship displacement.

CHAPTER 35 SYSTEM AND EQUIPMENT READY

Section 1 GENERAL PROVISIONS

35.1.1 General requirements

35.1.1.1 This Chapter applies to system and/or equipment ready for which technical requirements are specified for existing class notations[①].

35.1.1.2 For ships assigned relevant ready class notations in accordance with the requirements of this Chapter, corresponding class notations may be assigned upon completion of onboard installation/modification of system and/or equipment and subject to satisfactory survey by ISC, and ready class notations are withdrawn.

Section 2 READY CLASS NOTATIONS

35.2.1 Form of identification

35.2.1.1 Ready (X-i) is used as the form of identification of ready class notations, where "X" indicates class notation for system and/or equipment corresponding to the ready class notation; "i" indicates different ready levels corresponding to X. i=1 for completion of principled design, i=2 for completion of detailed design.

35.2.1.2 With regard to multiple systems and/or equipment ready, they may be filled in the parentheses after Ready. Different class notations are separated by commas (,), e.g. "video monitoring system ready level 1" and "shore connection system ready level 2" may be expressed as Ready (VDMS-1, AMPS-2).

Section 3 TECHNICAL REQUIREMENTS AND PLANS AND INFORMATION

35.3.1 Principled design ready

35.3.1.1 Technical requirements

(1) Comprehensive consideration is to be given to the space for the installation, arrangement and repair of the systems and/or equipment required on the ship, as well as the possible impact on the ship's arrangement, equipment, power load, structural strength, stability, tonnage and deadweight etc.

35.3.1.2 Plans and information

(1) The following plans and information are to be submitted for review as a minimum:

① instructions of the ready plan;

② ready-related principled design plans and information.

35.3.2 Detailed design ready

35.3.2.1 Technical requirements

(1) Based on 35.3.1.1 above, the ship also needs to satisfy applicable provisions of class notations corresponding to the system and/or equipment.

35.3.2.2 Plans and information

(1) The following plans and information are to be submitted for review as a minimum:

① instructions of the ready plan;

② instructions of the ready system and/or equipment;

③ ready-related detailed design plans and information;

④ applicable plans and information of the class notation corresponding to the system and/or equipment.

---

① "Existing class notations" mean those class notations in Table G etc. of Appendix 1 List of Class Notations, Chapter 2, PART ONE of the Rules, excluding existing ready class notations (e.g. EGC Ready (X)).

CHAPTER 36 ONBOARD CARBON CAPTURE SYSTEM

Section 1 GENERAL PROVISIONS

36.1.1 General requirements

36.1.1.1 This Chapter applies to ships applying for the Onboard Carbon Capture System notation, for the purpose of providing standards for the design, survey and operational safety of ships provided with OISC so as to minimize the harm to ships, crew members and the environment caused by OISC.

36.1.1.2 Ships provided with the onboard carbon capture system are, in addition to the provisions of this Chapter, to satisfy applicable requirements of others parts and chapters of the rules and relevant requirements of ISC Guidelines for Onboard Carbon Capture Systems.

36.1.2 Class notation

36.1.2.1 Ships complying with the provisions of this Chapter are assigned the onboard carbon capture system notation upon satisfactory survey:

OISC (Onboard Carbon Capture System)

36.1.2.2 For OISC ready ships, the ready notation and requirements are to satisfy relevant requirements of ISC Guidelines for Onboard Carbon Capture Systems.

36.1.3 Plans and information

36.1.3.1 The following plans and information are to be submitted for approval as a minimum:

(1) relevant piping system plan of onboard carbon capture system;

(2) power load calculations;

(3) electrical system plan of onboard carbon capture system.

36.1.3.2 The following plans and information are to be submitted for information as a minimum:

(1) technical description and installation plan of onboard carbon capture system, including:

① system design parameters;

② system carbon dioxide capture capacity calculation;

③ list of system equipment;

④ system arrangement plan.

(2) operation and maintenance manual of onboard carbon capture system;

(3) carbon dioxide absorber safety data sheet;

(4) risk assessment report of onboard carbon capture system.

36.1.3.3 The scope of plans and information submitted for approval may be expanded when deemed necessary by ISC.

Section 2 DESIGN AND ARRANGEMENT

36.2.1 System design

36.2.1.1 The onboard carbon capture system is to be able to adapt to the environmental and working conditions of the ship's operation.

36.2.1.2 The carbon dioxide capture capacity of the onboard carbon capture system is to meet the expected design objectives, and the capacity of carbon dioxide storage tank is to meet the expected design volume.

36.2.1.3 The strength and tightness design of the onboard carbon capture system is to meet the set conditions and the possible low temperature condition in case of leakage of carbon dioxide.

36.2.1.4 The onboard carbon capture system is to be provided with necessary redundant safety protection measures and capable of preventing and dealing with accidents.

36.2.1.5 The onboard carbon capture system is to be provided with monitoring, alarm and control systems.

36.2.1.6 The design of onboard carbon capture system is to facilitate shipboard operation and maintenance.

36.2.1.7 The energy supply (e.g. electricity, steam etc.) on board is to satisfy the expected operating requirements of the onboard carbon capture system.

36.2.1.8 The onboard carbon capture system is to minimize the potential risk to ships, essential equipment, personnel and the environment. Chemical substances in storage and use are to ensure that they will not cause harm to personnel and the environment.

36.2.2 Arrangement and safety requirements

36.2.2.1 Shipboard installation, arrangement and operation of onboard carbon capture system are to meet the following requirements:

(1) mechanical and high temperature protection is to be considered;

(2) life-saving appliances, muster station and means of escape are not to be affected;

(3) the impact of the change of ship tonnage on the applicable standards after the addition of the system;

(4) navigation bridge visibility is to comply with SOLAS regulation V/22 and the relevant provisions of the flag State;

(5) the normal operation of the ship's essential equipment (e.g. as main engines, generators and boilers, etc.) is not affected.

36.2.2.2 After the onboard carbon capture system is installed, the ship’s structural strength is to satisfy the requirements for longitudinal and local strength of the rules.

36.2.2.3 The effect of windage area, lightship center of gravity, heel and trim on ship stability is to be considered for ships provided with onboard carbon capture system.

36.2.2.4 The mechanical properties, chemical composition, manufacturing and testing of materials used in the equipment and pipelines of onboard carbon capture system are to comply with the relevant provisions of ISC Rules for Materials and Welding, and corrosion prevention measures are be considered (if necessary). Materials (including coatings) used in equipment, pipelines and components in contact with seawater is not to cause any harm to marine organisms.

36.2.2.5 Detectors are to be fitted where carbon dioxide leakage or accumulation is likely to occur. When the detector operates, audible and visual alarm signals are to be given on the bridge and in the onboard carbon capture system control station.

36.2.2.6 The installation and operation of the onboard carbon capture system is to minimize the impact on the fuel combustion device.

36.2.2.7 During the operation and maintenance of the onboard carbon capture system, all operations that may pose risks to personnel are to be provided with appropriate protective equipment on board.

Section 3 SURVEYS

36.3.1 General requirements

36.3.1.1 Equipment and components of the onboard carbon capture system are to satisfy the applicable requirements of Chapter 3, PART ONE of the rules.

36.3.1.2 Equipment constituting the onboard carbon capture system is to be subject to surveys and tests in accordance with approved plans and relevant standards.

36.3.2 Surveys during construction

36.3.2.1 Surveys and functional testing are to be carried out to devices, equipment, systems, components and installation of relevant pipelines of the onboard carbon capture system.

36.3.2.2 Sea trials are to be carried out to the system in accordance with the requirements of the sea trial programme

36.3.3 Surveys after construction

36.3.3.1 Ships provided with the onboard carbon capture system are to be subject to annual surveys, intermediate surveys and special surveys.

CHAPTER 37 ADDITIONAL REQUIREMENTS FOR CARRYING DRY CARGO IN BULK

Section 1 GENERAL PROVISIONS

37.1.1 General requirements

37.1.1.1 Ships which are intended to carry dry cargo in bulk, with a configuration different from that defined in 8.1.1.1, Chapter 8, PART TWO of the rules, are assigned the notation: SOLAS XII where the requirements of this Chapter are satisfied.

37.1.2 Additional requirements for SOLAS XII bulk cargo carriage

37.1.2.1 Ships applying for the SOLAS XII notation are, in addition to satisfying the applicable requirements SOLAS Chapter XII, to satisfy applicable requirements of Chapter 8, PART TWO of the rules based on specific configuration.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART NINE COMMON STRUCTURAL RULES FORBULK CARRIERS AND OIL TANKERS

Table of Contents

Chapter 1 RULE GENERAL PRINCIPLES 1
Section 1 APPLICATION 1
Section 2 RULE PRINCIPLES 8
Section 3 VERIFICATION OF COMPLIANCE 20
Section 4 SYMBOLS AND DEFINITIONS 26
Section 5 LOADING MANUAL AND LOADING INSTRUMENTS 44
Chapter 2 GENERAL ARRANGEMENT DESIGN 49
Section 1 GENERAL 49
Section 2 SUBDIVISION ARRANGEMENT 50
Section 3 COMPARTMENT ARRANGEMENT 52
Section 4 ACCESS AND ESCAPE ARRANGEMENT 55
Chapter 3 STRUCTURAL DESIGN PRINCIPLES 57
Section 1 MATERIAL 57
Section 2 NET SCANTLING APPROACH 68
Section 3 CORROSION ADDITIONS 73
Section 4 CORROSION PROTECTION 77
Section 5 LIMIT STATES 79
Section 6 STRUCTURAL DETAIL PRINCIPLES 83
Section 7 STRUCTURAL IDEALISATION 113
Chapter 4 LOADS 134
Section 1 INTRODUCTION 134
Section 2 DYNAMIC LOAD CASES 137
Section 3 SHIP MOTIONS AND ACCELERATIONS 149
Section 4 HULL GIRDER LOADS 154
Section 5 EXTERNAL LOADS 162
Section 6 INTERNAL LOADS 182
Section 7 DESIGN LOAD SCENARIOS 209
Section 8 LOADING CONDITIONS 213
Appendix 1 HOLD MASS CURVES 275
Chapter 5 HULL GIRDER STRENGTH 288
Section 1 HULL GIRDER YIELDING STRENGTH 288
Section 2 HULL GIRDER ULTIMATE STRENGTH 304
Section 3 HULL GIRDER RESIDUAL STRENGTH 307
Appendix 1 DIRECT CALCULATION OF SHEAR FLOW 310
Appendix 2 HULL GIRDER ULTIMATE CAPACITY 317
Chapter 6 HULL LOCAL SCANTLING 329
Section 1 GENERAL 329

Section 2 LOAD APPLICATION 330
Section 3 MINIMUM THICKNESSES 333
Section 4 PLATING 335
Section 5 STIFFENERS 340
Section 6 PRIMARY SUPPORTING MEMBERS AND PILLARS 342
Chapter 7 DIRECT STRENGTH ANALYSIS 346
Section 1 STRENGTH ASSESSMENT 346
Section 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS 349
Section 3 LOCAL STRUCTURAL STRENGTH ANALYSIS 383
Chapter 8 BUCKLING 407
Section 1 GENERAL 407
Section 2 SLENDERNESS REQUIREMENTS 410
Section 3 PRESCRIPTIVE BUCKLING REQUIREMENTS 417
Section 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS 421
Section 5 BUCKLING CAPACITY 433
Appendix 1 STRESS BASED REFERENCE STRESSES 456
Chapter 9 FATIGUE 460
Section 1 GENERAL CONSIDERATIONS 460
Section 2 STRUCTURAL DETAILS TO BE ASSESSED 465
Section 3 FATIGUE EVALUATION 480
Section 4 SIMPLIFIED STRESS ANALYSIS 495
Section 5 FINITE ELEMENT STRESS ANALYSIS 517
Section 6 DETAIL DESIGN STANDARD 537
Chapter 10 OTHER STRUCTURES 562
Section 1 FORE PART 562
Section 2 MACHINERY SPACE 571
Section 3 AFT PART 575
Section 4 TANKS SUBJECT TO SLOSHING 579
Chapter 11 SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING 586
Section 1 SUPERSTRUCTURES AND DECKHOUSES 586
Section 2 BULWARK AND GUARD RAILS 590
Section 3 EQUIPMENT 593
Section 4 SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS 594
Section 5 SMALL HATCHWAYS 600
Chapter 12 CONSTRUCTION 606
Section 1 CONSTRUCTION AND FABRICATION 606
Section 2 FABRICATION BY WELDING 609
Section 3 DESIGN OF WELD JOINTS 612

Chapter 13 SHIP IN OPERATION - RENEWAL CRITERIA 629

Section 1 PRINCIPLES AND SURVEY REQUIREMENTS 629

Section 2 ACCEPTANCE CRITERIA 631

ISC Appendix A WAVE LOAD DIRECT CALCULATION METHOD BASED ON EQUIVALENT DESIGN WAVE METHOD 634

ISC Appendix B SUPPLEMENTARY REQUIREMENTS FOR DIRECT CALCULATION LOAD CONDITIONS 645

ISC Appendix C ASSESSMENT OF ULTIMATE STRENGTH OF HULL GIRDERS USING NON-LINEAR FEM 652

ISC Appendix D RECOMMENDATION FOR ASSESSING DESIGN INSTANCES BASED ON APPLICATION OF ALTERNATIVE METHODS 655

IN THE HULL STRUCTURAL DESIGN OF CSR SHIPS 655

Chapter 1 BULK CARRIERS 658

Section 1 GENERAL ARRANGEMENT DESIGN 658

Section 2 STRUCTURAL DESIGN PRINCIPLES 660

Section 3 HULL LOCAL SCANTLINGS 666

Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS L<150M 679

Section 5 CARGO HATCH COVERS 690

Section 6 ADDITIONAL CLASS NOTATION GRAB 708

Chapter 2 OIL TANKERS 709

SECTION 1 GENERAL ARRANGEMENT DESIGN 709

SECTION 2 STRUCTURAL DESIGN PRINCIPLES 711

SECTION 3 HULL LOCAL SCANTLING 712

SECTION 4 HULL OUTFITTING 730

ISC Appendix A IACS REC.14 - HATCH COVER SECURING AND TIGHTNESS 732

ISC Appendix B IACS REC.34 - Standard Wave Data 736

Chapter 1 RULE GENERAL PRINCIPLES

Section 1 APPLICATION

1 SCOPE OF APPLICATION

1.1 General

1.1.1

These Rules apply to the following ships:

a) Bulk carriers and double hull oil tankers and;
b) Being self-propelled ships with unrestricted navigation, and;
c) Contracted for construction on or after 1st July 2015.

ISC 1.1.1a Oil tankers and bulk carriers having a length of 150m and above and contracted for construction on and after 1 July 2016 are to comply with applicable ISC Guidelines for Construction Monitoring of Hull Structures(2014) and to be assigned the class notation CM.

Note1: Unrestricted navigation means that the ship is not subject to any geographical restrictions (i.e. any oceans, any seasons) except that limited by the ship's capability for operation in ice.

Note2: The 'contracted for construction' means the date on which the contract to build the ship is signed between the prospective owner and the builder. For further details regarding the date of 'contracted for construction', refer to IACS Procedural Requirement (PR) No. 29.

1.1.2

These Rules apply to ships constructed of welded steel structures and composed of stiffened plate panels. The ship's structure is to be longitudinally or transversely framed with full transverse bulkheads and intermediate web frames.

The typical arrangements of ships covered by the rules assume that the structural arrangements include:

- Double bottom, the depth of which is to be in accordance with applicable statutory requirements.
- Engine room located aft of the cargo tank/hold region.

1.1.3

Ships for which these Rules are not applicable are to comply with the relevant Rules of the Society.

ISC 1.1.3a Unless provided otherwise, "the Society" in this PART means "ISC".

1.2 Scope of application for bulk carriers

1.2.1

These Rules apply to the hull structures of single side skin and double side skin bulk carriers having a freeboard length L_{LL} of 90 m or above.

Bulk carriers are ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo hold region and intended primarily to carry dry cargoes in bulk. Typical arrangements of bulk carriers are shown in Figure 1.

Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, see typical arrangements in Figure 1, and other cargo holds are constructed without hopper tank and/or topside tanks, see examples of a transverse section in Figure 2, are to comply with the strength criteria defined in these Rules.

These Rules are not applicable to the following ship types:

- Ore carriers.
- Combination carrier.
- Woodchip carrier.
- Cement, fly ash and sugar carriers provided that loading and unloading is not carried out by grabs heavier than 10 tons, power shovels and other means which may damage cargo hold structure.
- Ships with inner bottom construction adapted for self-unloading.

1.3 Scope of application for oil tankers

a) *Length and structural arrangement application*

These Rules apply to the hull structures of double hull oil tankers having a freeboard length L_{LL} of 150 m or above. Oil tanker is defined as a ship which has to comply with Annex I of MARPOL73/78.

The typical arrangements of oil tankers covered by the rules are shown in Figure 3 and assume that the structural arrangements include:

- Double side structure with breadth in accordance with statutory requirements.
- Side longitudinal, centreline longitudinal or transverse bulkheads of plane, corrugated or double skin construction.
- Single deck structure.

The cross sections shown in Figure 3 are typical examples only and other variations of cross tie and web frame arrangements are also covered.

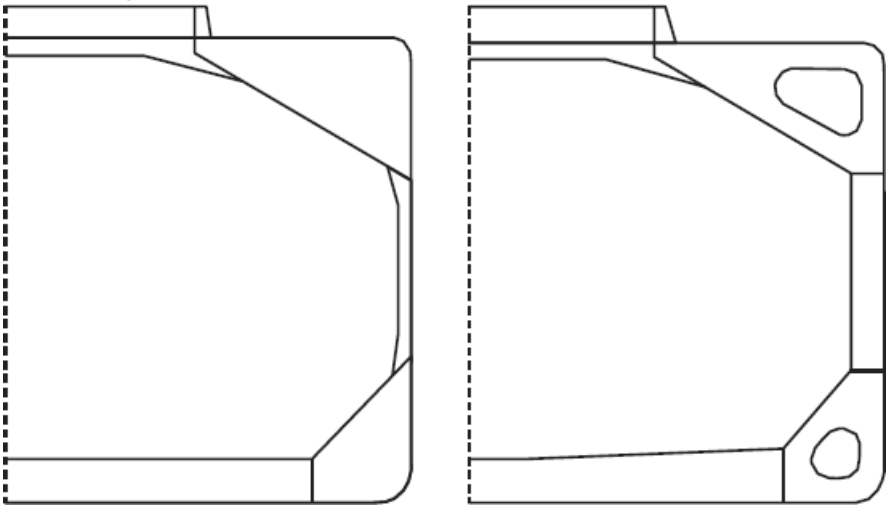


Figure 1 Typical arrangements of bulk carriers

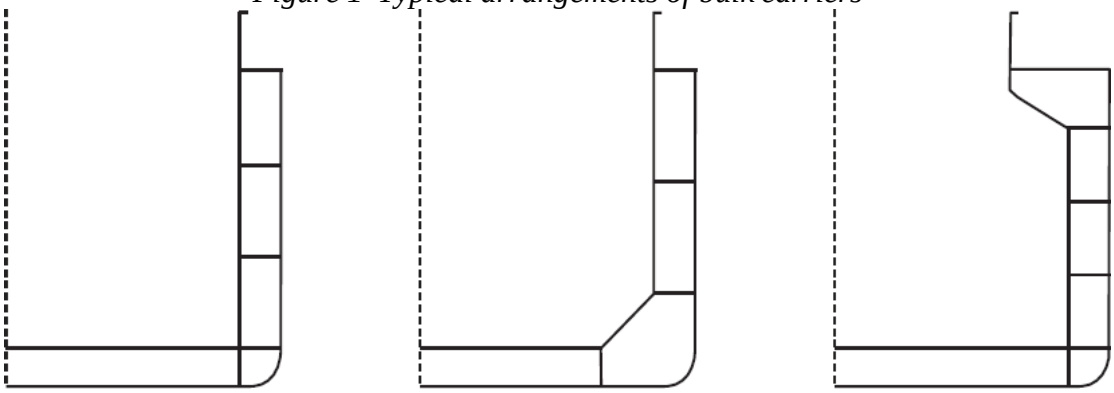


Figure 2 Examples of transverse sections of cargo hold without hopper tank and/or topside tank

b) **Cargo temperature application**

The Rules are based on the following design temperatures for the cargo:

a) maximum temperature: 80°C
b) minimum temperature: 0°C.

2 *RULE APPLICATION*

2.1 Rule description

a) *Rule structure*

The rules contain 2 parts:

- Part 1: General hull requirements.
- Part 2: Ship types.

The parts are structured in chapters giving instructions for detail application and requirements which are applied in order to satisfy the rule objectives.

b) *Numbering*

The system of numbering is given in Table 1.

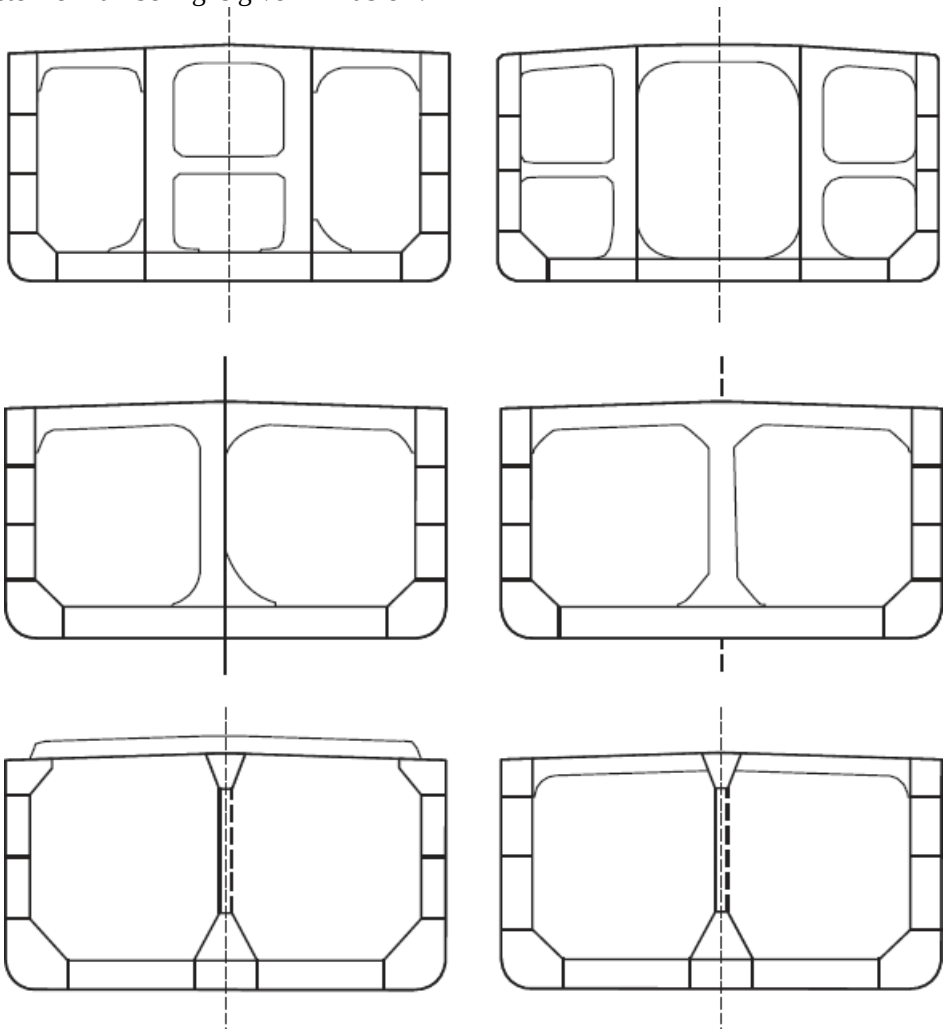


Figure 3 Typical arrangements of double hull oil tankers

Rule numbering and abbreviations **Table 1**

Order	Levels	Example	Abbreviations
1	Part	Part 1 – General Hull Requirements	Pt 1
2	Chapter	Chapter 1 – Rule General Principle	Ch 1
3	Section	Section 1 – Application	Sec 1
4	Article	1. Scope of Application	[1]
5	Sub-article	1.1 General	[1.1]
6	Requirements	1.1.1 These Rules apply to...	[1.1.1]

2.2 Rule Requirements

a) *Part 1*

Part 1 of the Rules provides requirements common to all ship types as follow:

- Chapter 1: Rule General Principles.
- Chapter 2: General Arrangement Design.
- Chapter 3: Structural Design Principles.
- Chapter 4: Loads.
- Chapter 5: Hull Girder Strength.
- Chapter 6: Hull Local Scantling.
- Chapter 7: Direct Strength Analysis.
- Chapter 8: Buckling.
- Chapter 9: Fatigue.
- Chapter 10: Other Structure.
- Chapter 11: Superstructure, Deckhouses and Hull Outfitting.
- Chapter 12: Construction.
- Chapter 13: Ship in Operation - Renewal Criteria.

The provisions of the Ch 1, 2, 3, 4, 5, 6, 8, 12, 13 and Ch 10, Sec 4 are applicable all over the ships length.

The Ch 7, 9, 10 and 11 define their own scope of application.

b) *Part 2*

Part 2 of the Rules provides requirements coming in addition to those of Part 1 specific for ship types and is divided as follow:

- Chapter 1: Bulk Carriers.
- Chapter 2: Oil Tankers.

c) *Application of the Rules*

The ship arrangement and scantlings are to comply with the relevant parts and chapters of the Rules as it is given in Figure 4.

d) *General criteria*

The ship arrangement, the proposed details and the offered scantling in net or gross, as the case may, are to comply with the requirements and the minimum scantling given in the Rules.

2.3 Structural requirements

a) *Materials and welding*

The Rules applies to welded hull structures made of steel having characteristics complying with requirements in Ch 3, Sec 1. The Rules applies also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 3, Sec 1.

Ships whose hull materials are different than those given in the first paragraph are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present rules.

2.4 Ship parts

a) *General*

For the purpose of application of the present rules, the ship is considered as divided into the following five parts:

- Fore part.
- Cargo hold region.
- Machinery space.
- Aft part.
- Superstructures and deckhouses.

b) *Fore part*

The fore part is that part of the ship located forward of the collision bulkhead, i.e.:

- The fore peak structures.

- The stem.

c) *Cargo hold region*

The cargo hold region is the part of the ship that contains cargo holds, cargo tanks, and slop tanks. It includes the full breadth and depth of the ship, the collision bulkhead and the transverse bulkhead at its aft end. The cargo hold region does not include the pump room, if any.

d) *Machinery space*

The machinery space is the part of the ship between the aft peak bulkhead and the transverse bulkhead at the aft end of the cargo hold region and includes the pump room, if any.

e) *Aft part*

The aft part includes the structures located aft of the aft peak bulkhead.

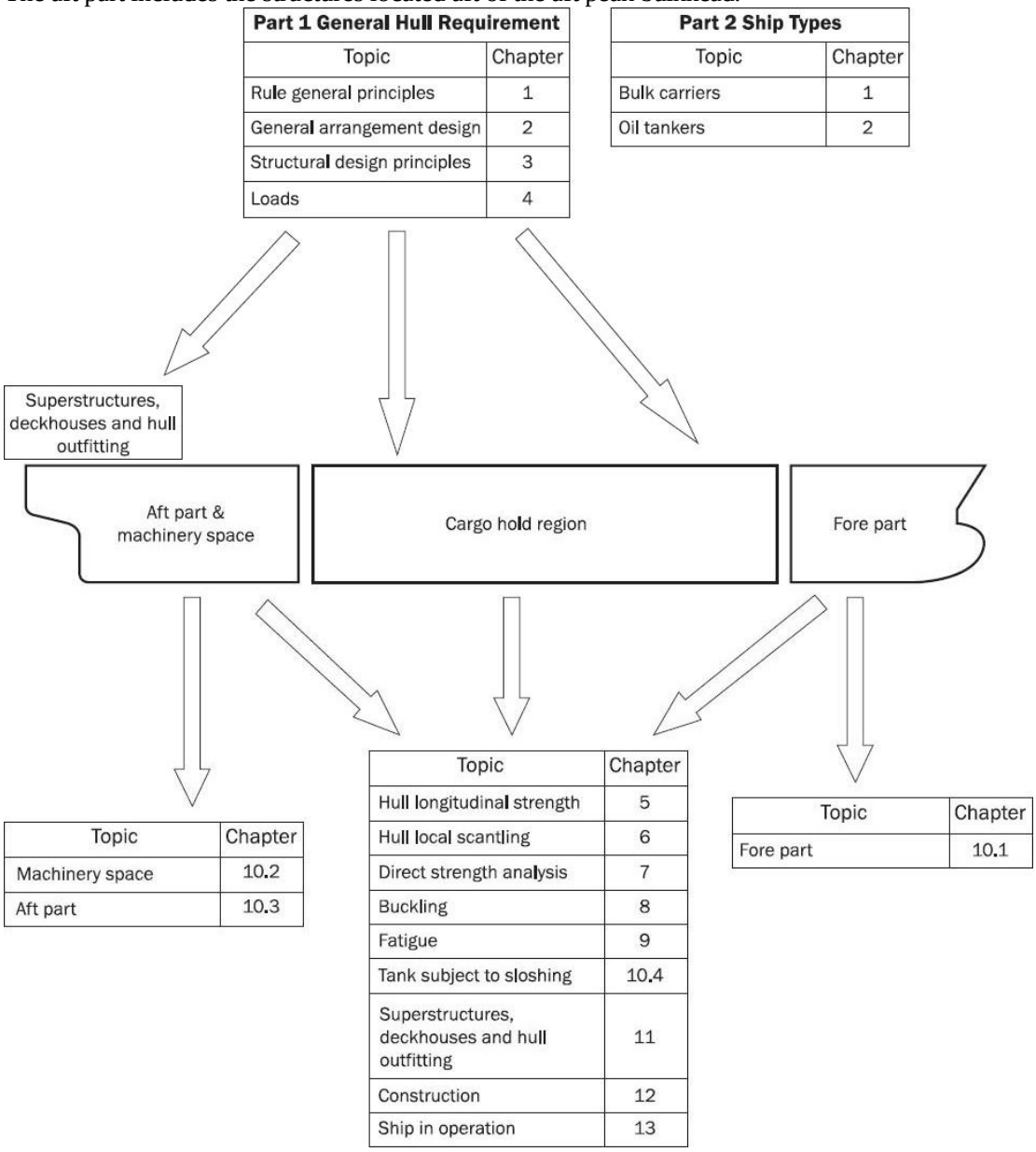


Figure 4 Application of Rules

f) **Superstructures and deckhouses**

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04 *B*.

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply

with the definition of a superstructure.

2.5 Limits of application to lifting appliances

a) **Definition**

The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance, crane pedestals, masts, king posts, derrick heel seatings, etc, excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any removable parts), only for that part directly interacting with the hull structure.

b) *Rule application for lifting appliances*

The fixed parts of lifting appliances and their connections to the ship's structure may be covered by the Society's rules for lifting appliances, and/or by the certification (especially the issuance of the Register of ship's lifting appliances and cargo handling gear) of lifting appliances when required.

ISC 2.5.2a The supporting structures of lifting appliances are to comply with the requirements of 4, Section 4, Chapter 11 of this PART.

c) *Structures supporting fixed lifting appliances*

The design of the structure supporting fixed lifting appliances and the structure that might be called to support a mobile appliance is to be designed taking into account the additional loads that may be imposed on them by the operation of the appliance and environmental conditions as declared by the builder or its sub-contractors.

2.6 Novel designs

2.6.1

Ships with novel features or unusual hull design are to comply with Ch 1, Sec 3, [6.2].

3 CLASS NOTATIONS

3.1 Class notation CSR

a) **Application**

In addition to the class notations granted by the Society and to the service features and additional class notations defined hereafter, ships fully complying with these Rules are assigned the notation CSR.

3.2 Class notation for bulk carriers

a) **Additional service features BC-A, BC-B and BC-C**

The following requirements apply to ships, as defined in [1.2.1], having a freeboard length L_{LL} of 150 m or above. Bulk carriers are to be assigned one of the following additional service features:

a) BC-A: For bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.
b) BC-B: For bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions.
c) BC-C: For bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

The following additional service features are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- {Maximum cargo density in t/m3} for additional service features BC-A and BC-B if the maximum cargo density is less than 3.0 t/m3, see also Ch 4, Sec 8, [4.1].
- {No MP} for all additional service features when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Ch 4, Sec 8, [4.2.2].
- {Holds a, b, … may be empty} for additional service feature BC-A, see also Ch 4, Sec 8, [4.1].
- {Block loading} for additional service feature BC-A, when the ship is intended to

operate in alternate block load condition, see also Ch 4, Sec 8, [4.2.3] ,item d.

b) *Additional class notation GRAB [X]*

The additional class notation GRAB [X] is mandatory for ships having one of the additional service features BC- A or BC-B, according to [3.2.1]. For these ships, the requirements for the GRAB [X] notation given in Pt 2, Ch 1, Sec 6 are to comply with for an unladen grab weight X taken not less than:

- 35 t for ships with $L \geq 250$ m,
- 30 t for ships with 200 m $\leq L < 250$ m,
- 20 t otherwse.

For all other ships, the additional class notation GRAB [X] is voluntary.

4 *APPLICATION OF THE RULES OF THE SOCIETY*

4.1 Structural parts not covered by these Rules

4.1.1.

Designer should take care that parts of the structure that these Rules do not cover comply with the relevant requirements of the Society's Rule.

Section 2 RULE PRINCIPLES

1 GENERAL

1.1 Rule objectives

1.1.1

The objectives of the Rules are to establish the classification minimum requirements to mitigate the risks of major hull structural failure in order to help improve the safety of life, environment and property and to contribute to the durability of the hull structure for the ship's design life.

1.1.2

The sub-sections contain:

- The general assumptions pertaining to the design, construction and operation of the ship and give information on the assumed roles of the Society, builders, designers and owners.
- The design basis which specifies the premises on which the Rules are based in terms of design parameters and assumptions about the ship operation.
- The design principles which define the fundamental principles used for the structural requirements in the Rules with respect to loads and structural capacity.
- The rule design methods which describe how the design principles are applied and the criteria are used in view of [1.1.1].

2 *GENERAL ASSUMPTIONS*

2.1 International and national regulations

2.1.1

Ships are to be designed, constructed and operated in compliance with the regulatory framework prescribed by the International Maritime Organisation (IMO) and implemented by National Administrations or the Society on their behalf. The builder is to give due consideration to the influence on the structural design and arrangement from the relevant requirements of the International Labour Organization (ILO) implemented by National Administrations or the Society on their behalf.

2.1.2

The Rules are based on the assumption that the applicable statutory requirements are complied with.

2.2 *Application and implementation of the Rules 2.2.1*

The Society develops and publishes the rules for classification of ships, containing minimum requirements for the hull structure and essential engineering systems. The Society verifies compliance with the classification requirements and the applicable international regulations when authorised by a National Administration during design, construction and operation of the ship.

2.2.2

These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. In order to achieve the safety level targeted by the Rules, a number of aspects related to design, construction and operation of the ship are assumed to be adhered to by the parties involved in the application and implementation of the Rules. A summary of these assumptions are given in the following:

a) General aspects:
   - Relevant information and documentation involved in the design, construction and operation is communicated between the builder, the designer, the Society and the owner as agreed between builder and owner. Design documentation according to Rule requirements is provided.
   - Quality systems are applied to the design, construction, operation and maintenance activities by owners and other relevant parties to ensure the compliance with the

requirements of the Rules.

b) Design aspects:
   - The owner specifies the intended use of the ship, and the ship is designed according to operational requirements as well as the structural requirements given in the Rules.
   - The builder identifies and documents the operational limits for the ship so that the ship can be safely and efficiently operated within these limits.
   - Verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations.
   - The design is performed by appropriately qualified, competent and experienced personnel.
   - The Society performs a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification Rules.
   - For spaces where lighting and ventilation are to be fitted, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of International Conventions such as SOLAS and MLC2006 Regulation 3.1 - Accommodation and recreational facilities, and Society's rules if any. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.
   - For continually manned spaces where noise is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of SOLAS Ch II-1, Reg.3-12 and "The Code on Noise Levels Onboard Ships" adopted at MSC.337(91).
   - For continually manned spaces where vibration is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of relevant statutory requirements such as MLC 2006 Regulation 3.1 - Accommodation and recreational facilities. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.

c) Construction aspects:
   - The builder provides adequate supervision and quality control during the construction.
   - Construction is carried out by qualified and experienced personnel.
   - Workmanship, including alignment and tolerances, is in accordance with acceptable shipbuilding standards.
   - The Society performs surveys to verify that the construction and quality control are in accordance with the classification features of approved plans and procedures.

d) Operational aspects:
   - Personnel involved in operations are aware of, and comply with, the operational limitations of the ship.
   - Operations personnel receive sufficient training such that the ship is properly handled so that the loads and resulting stresses imposed on the structure are minimised.
   - The ship is maintained in adequate condition and in accordance with the Society survey scheme and international and national regulations and requirements.
   - The Society performs surveys to verify that the ship is maintained in class in accordance with the Society survey scheme.

ISC 2.2.2a The applicable requirements in ISC Guidelines on Application of Marine Ergonomics may be applied as an ergonomic standard in [2.2.2] b).

3 *DESIGN BASIS*

3.1 General

3.1.1

This sub-section specifies the design parameters and the assumptions about the ship operation that are used as the basis of the design principles of the Rules.

3.1.2
Ships are to be designed to withstand, in the intact condition, the environmental conditions as defined in [5.3.2] and [5.3.3] anticipated during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations have to include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

3.1.3 *Residual strength*
Ships having a freeboard length L_{LL} of 150 m or above are to be designed to have sufficient reserve strength to withstand the loads in damaged conditions, e.g. collision, grounding or flooded scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour as specified in Ch 5, Sec 3.

3.1.4 *Finite element analysis*
The scantling of the structural members within the cargo hold region of ships having a freeboard length L_{LL} of 150 m or above is to be assessed according to the requirements specified in Pt 1, Ch 7.

3.1.5 *Fatigue life*
Ships having a freeboard length L_{LL} of 150 m or above are to be assessed according to the design fatigue life for structural details specified in Pt 1, Ch 9.

3.1.6
The Rules are applicable for ships in compliance with the specified design basis. Special consideration is given to deviations from this design basis.

ISC 3.1.6a This PART applies to ships complying with the design basis specified in this Section. For ships which are not designed on this basis, equivalence or substitution is to be granted in accordance with the requirements in ISC Appendix D of PART 9-1.

3.1.7
The design basis used for the design of each ship, as communicated by the builder to the owner, is to be documented and submitted to the Society as part of the design review and approval. All changes of the design basis are to be formally advised to the Society and the owner for approval.

3.2 *Hull form*
limit 3.2.1
The Rules assume the following hull form with respect to environmental loading:

- $L < 500$ m
- $C_B > 0.6$
- $L/B > 5$
- $B/D < 2.5$

For ships over 350 m in length, special consideration is to be made for the wave loads by the Society.

ISC 3.2.1a For ships not complying with the conditions of 3.2.1, the dynamic hull girder loads, ship motions, ship accelerations and sea water dynamic pressures are to be calculated in accordance with the following requirements:
1) Where the ship length L is greater than 350 m,
a) Vertical wave bending moments, vertical wave shear forces, horizontal wave bending moments and torsional moments of hull girder are to be calculated respectively in accordance with the requirements of the following chapters and sections, the greater of which is used for strength assessment and fatigue assessment:

- *ISC Appendix A of PART 9-1;*
- *Section 4, Chapter 4 of PART 9-1 (CB is to be taken not less than 0.6 during*

calculation);

b) Ship motions, ship accelerations and sea water dynamic pressures are to be calculated respectively in accordance with the requirements of the following chapters and sections and used for strength assessment and fatigue assessment:

- *ISC Appendix A of PART 9-1;*
- *Chapter 4 of PART 9-1.*

2) Where the ship length L is not greater than 350 m, for ships not complying with conditions of other hull form limit in 3.2.1,

a) Vertical wave bending moments and vertical wave shear forces of hull girders are to be calculated according to Section 4, Chapter 4 of PART 9-1 (C_B is to be taken not less than 0.6 during calculation) and used for strength assessment and fatigue assessment;

b) Horizontal wave bending moments and torsional moments of hull girder are to be calculated respectively in accordance with the requirements of the following chapters and sections, the greater of which is used for strength assessment and fatigue assessment:

- *ISC Appendix A of PART 9-1;*
- *Section 4, Chapter 4 of PART 9-1 (C_B is to be taken not less than 0.6 during calculation);*

c) Ship motions, ship accelerations and sea water dynamic pressures are to be calculated respectively in accordance with the requirements of the following chapters and sections and used for strength assessment and fatigue assessment:

- *ISC Appendix A of PART 9-1;*
- *Chapter 4 of PART 9-1.*

3.3 *Design life*

3.3.1

A design life of 25 years is assumed for selecting ship design parameters. The specified design life is the nominal period that the ship is assumed to be exposed to operating conditions.

3.4 *Environmental conditions*

3.4.1 North Atlantic wave environment

The rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

3.4.2 *Wind and current*

The effects of wind and current with regard to the strength of the structure are not considered.

3.4.3 *Ice*

The effects of ice and ice accretion are not taken into account by the Rules.

3.4.4 *Design temperatures*

The Rules assume that the structural assessment of hull strength members is valid for the following design temperatures:

- Lowest mean daily average temperature in air is -10°C.
- Lowest mean daily average temperature in seawater is 0°C.

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters are subject to the requirements as specified by the Society.

In the above, the following definitions apply:

Mean: Statistical mean over observation period (at least 20 years).

Daily Average: Average during one day and night.

Lowest: Lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

ISC 3.4.4a For ships operating for long periods in areas with lower mean daily average temperature, the steels used for hull structures exposed to low temperature are to comply with the requirements of ISC 2.4.1a to ISC 2.4.1e, Section 1, Chapter 3 of this PART.

3.4.5 *Thermal loads*
The effects of thermal loads and residual stresses are not taken into account in the Rules.

3.5 *Operating conditions*
3.5.1
The Rules specify minimum loading conditions that are to be assessed for compliance.
Specification of loading conditions other than those required by the Rules is the responsibility of the owner. These other loading conditions are to be documented and also be assessed for compliance.

3.5.2
The Rules assume the following:

- The ballast cargo hold of bulk carriers is not to be partly filled in seagoing operations.
- Ballasting and deballasting operations in the ballast cargo hold of bulk carriers are not to be performed when the weather is not fair.

3.6 *Operating draughts*
3.6.1
The design operating draughts are to be specified by the builder/designer subject to acceptance by the owner and are to be used to derive the appropriate structural scantlings. All operational loading conditions in the loading manual are to comply with the specified design operating draughts. The following design operating draughts are as a minimum to be considered:

3.6.1 Scantling draught for the assessment of structure.

3.6.2 Minimum ballast draught at midship for assessment of structure.

3.6.3 Minimum heavy ballast draught at midship for assessment of bulk carrier structure.

3.6.4 Minimum forward draughts for the assessment of bottom structure forward subjected to slamming loads, $T_{F\text{-}e}$ and $T_{F\text{-}f}$, with and without ballast tanks in way filled.
$T_{F\text{-}e}$ and $T_{F\text{-}f}$ are defined in Ch 4, Sec 5, [3.2.1]

- For oil tankers: maximum draughts amidships for both conditions:
  - with all cargo tanks abreast empty.
  - with centre cargo tank empty and wing cargo tanks full.
  - with centre cargo tank full and wing cargo tanks empty.
- For bulk carriers carrying steel coils: maximum draught amidships for steel coil loading conditions.

3.7 *Internal environment*
3.7.1 Oil cargo density for strength assessment
A density of 1.025t/m^3, or a higher value if specified by the designer, is to be used for oil cargoes for the strength assessment of all relevant tank structures.

3.7.2 *Oil cargo density for fatigue assessment*
For the fatigue assessment of cargo tank structures, the mean density is to be taken as 0.9t/m^3, or a higher value if specified by the designer.

3.7.3 *Dry cargo density*
The density for dry bulk cargo is to be taken according to the specifications in Ch 4, Sec 6, [2.3].

3.7.4 *Water ballast density*
A density of 1.025t/m^3 is to be used for water ballast.

3.8 *Structural construction and inspection 3.8.1*
The structural requirements included in the Rules are developed with the assumption that construction and repair follow acceptable shipbuilding and repair standards and tolerances. The Society may require that additional attention is paid to critical areas of the structure by the builder during construction and by the owner for repair after the ship's delivery.

3.8.2
As an objective, ships are to be built in accordance with controlled quality production standards using approved materials as necessary.

3.8.3
The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure is subject to appropriate monitoring by the owner once the ship is in operation and to periodical survey in accordance with Society rules and regulations.

3.8.4
Tank strength and tightness testing are to be carried out as a part of the verification scheme according to the Rules and /or documents of the individual Society which incorporate IACS UR S14.

3.8.5
Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures. It is assumed that the owner has approved these builder specifications.

3.9 *Maximum service speed 3.9.1*
The maximum service speed is to be specified in the design specification. Although the hull structure verification criteria takes into account the service speed this does not relieve the responsibilities of the owner and personnel to properly handle the ship, see item (d) in [2.2.2].

3.10 *Owner's extras*
3.10.1
Owner's specification of requirements above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

- Vibration analysis.
- Maximum percentage of high strength steel.
- Additional scantlings above that required by the Rules.
- Additional design margin on the loads specified by the Rules, etc.
- Improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent. Owner's extras are not specified by these Rules. Owner's extras, if any, that may affect the structural design are to be clearly specified in the design documentation.

4 DESIGN PRINCIPLES
4.1 Overall principles
4.1.1 Introduction
This sub-section defines the underlying design principles of the Rules in terms of loads, structural capacity models and assessment criteria and also construction and in-service aspects.

4.1.2 *General*
The Rules are based on the following overall principles:

- The safety of the structure can be assessed by addressing the potential structural failure mode(s) when the ship is subjected to operational loads and environmental loads/conditions.
- The design complies with the design basis, see Ch 1, Sec 3.
- The structural requirements are based on consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

The ship's structure is designed such that:

- It has a degree of redundancy. The ship's structure should work in a hierarchical manner and, in principle, failure of structural elements lower down in the hierarchy do not result in immediate consequential failure of elements higher up in the hierarchy.
- It has sufficient reserve strength to withstand the wave and internal loads in damaged

conditions that are reasonably foreseeable e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.

- The incidence of in-service cracking is minimised, particularly in locations which affect the structural integrity or containment integrity, affect the performance of structural or other systems or are difficult to inspect and repair.
- It has adequate structural redundancy to survive in the event that the structure is accidentally damaged by a minor impact leading to flooding of any compartment.

4.1.3 *Limit state design principles*

The rules are based on the principles of limit state design.

Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design scenarios identified. For each retained failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states.

The limit states defined in Ch 3, Sec 5 are divided into the four categories: Serviceability Limit State (SLS), Ultimate Limit State (ULS), Fatigue Limit State (FLS) and Accidental Limit State (ALS).

The Rules include requirements to cover the relevant limit states for the various parts of the structure.

4.2 *Loads*

4.2.1 Design load scenarios

The structural assessment of the structure is based on the design load scenarios encountered by the ship. Refer to Ch 4, Sec 7.

The design load scenarios are based on static and dynamic loads as given below:

- Static design load scenario (S):
  Covers application of relevant static loads and typically covers load scenarios in harbour, sheltered water, or tank testing.
- Static plus Dynamic design load scenario (S+D):
  Covers application of relevant static loads and simultaneously occurring dynamic load components and typically cover load scenarios for seagoing operations.
- Impact design load scenario (I):
  Covers application of impact loads such as bottom slamming and bow impact encountered during seagoing operations.
- Sloshing design load scenario (SL):
  Covers application of sloshing loads encountered during seagoing operations.
- Fatigue design load scenario (F):
  Covers application of relevant dynamic loads.
- Accidental design load scenario (A):
  Covers application of some loads not occurring during normal operations.

4.3 *Structural capacity assessment*

4.3.1 General

The basic principle in structural design is to apply the defined design loads, identify plausible failure modes and employ appropriate capacity models to verify the required structural scantlings.

4.3.2 *Capacity models for ULS, SLS and ALS*

The strength assessment method is to be capable of analysing the failure mode in question to the required degree of accuracy.

The structural capacity assessment methods are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

The formulae used to determine stresses, deformations and capacity are deemed appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

4.3.3 *Capacity models for FLS*

The fatigue assessment method provides Rule requirements to assess structural details against fatigue failure.

The fatigue capacity model is based on a linear cumulative damage summation (Palmgren-Miner's rule) in combination with a design S-N curve, a reference stress range and an assumed long-term stress distribution curve.

The fatigue capacity assessment models are in either a prescriptive format or require the use of more advanced calculations, such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

4.3.4 *Net scantling approach*

The objective of the net scantling approach is to:

- Provide a relationship between the thickness used for strength calculations during the newbuilding stage and the minimum thickness accepted during the operational phase.
- Enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

The net scantling approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas, such as primary supporting members and the hull girder. Both the local and global corrosion are used as a basis for the newbuilding review and are to be assessed during operation of the ship.

No credit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

The application of the net thickness approach to assess the structural capacity is specified in Ch 3, Sec 2.

4.3.5 *Intact structure*

All strength calculations for ULS, SLS and FLS are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is assessed for ALS.

5 RULE DESIGN METHODS

5.1 General

5.1.1 Design methods

Scantling requirements are specified to cover the relevant limit states (ULS, SLS, FLS and ALS) as necessary for various structural parts.

The criteria for the assessment of the scantlings are based on one of the following design methods:

- Working Stress Design (WSD) method, also known as the permissible or allowable stress method.
- Partial Safety Factor (PSF) method, also known as Load and Resistance Factor Design (LRFD).

For both WSD and PSF, two design assessment conditions and corresponding acceptance criteria are given. These conditions are associated with the probability level of the combined loads, A and B.

- The WSD method has the following composition:

  $W_{stat} \leq \eta_1 R$ for condition A.

  $W_{stat} + W_{dyn} \leq \eta_2 R$ for condition B.

  where:

  W_{stat}: Simultaneously occurring static loads (or load effects in terms of stresses).

  W_{dyn}: Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components.

  R : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity).

  i : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

- The PSF method has the following composition:

$$\gamma_{stat-1} W_{stat} + \gamma_{dyn-1} W_{dyn} \leq \frac{R}{\gamma_R} \text{ for condition A.}$$

$$\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \leq \frac{R}{\gamma_R} \text{ for condition B.}$$

where:

γ_{stat-i} : Partial safety factor that accounts for the uncertainties related to static loads.

γ_{dyn-i} : Partial safety factor that accounts for the uncertainties related to dynamic loads.

γ_R : Partial safety factor that accounts for the uncertainties related to structural capacity.

The acceptance criteria for both the WSD method and PSF method are calibrated for the various requirements such that consistent and acceptable safety levels for all combinations of static and dynamic load effects are derived.

5.2 *Minimum requirements*

5.2.1

Minimum requirements specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum is not allowed.

The minimum requirements are usually in one of the following forms:

- Minimum thickness, which is independent of the specified minimum yield stress.
- Minimum stiffness and proportion, which are based on buckling failure modes.

5.3 *Load-capacity based requirements*

5.3.1 General

In general, the Working Stress Design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria where the Partial Safety Factor (PSF) method is applied. The partial safety factor format is applied for this highly critical failure mode to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set, as given in Table 2. The table is schematic and only intended to give an overview.

Load based prescriptive requirements provide scantling requirements for all plating, local support members, most primary supporting members and the hull girder and cover all structural elements including deckhouses, foundations for deck equipment.

In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

5.3.2 *Design loads for SLS, ULS and ALS*

The structural assessment of compartment boundaries, e.g. bulkheads, is based on loading condition deemed relevant for the type of ship and the operation the ship is intended for.

To provide consistency of approach, standardised Rule values for parameters, such as GM, R_{roll}, T_{sc} and C_B are applied to calculate the Rule load values.

The probability level of the dynamic global, local and impact loads (see Table 1) is 10-8 and is derived using the long-term statistical approach.

The probability level of the sloshing loads (see Table 1) is 10^{-4}.

The design load scenarios for structural verification apply the applicable simultaneously acting local and global load components. The relevant design load scenarios are given in Ch 4, Sec 7.

The simultaneously occurring dynamic loads are specified by applying a dynamic load combination factor to the dynamic load values given in Ch 4. The dynamic load combination factors that define the dynamic load cases are given in Ch 4, Sec 2.

Design load conditions for the hull girder ultimate strength are given in Ch 5, Sec 2.

5.3.3 *Design loads for FLS*

For the fatigue requirements given in Ch 9, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-2} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding

stresses.

The considered wave induced loads include:

- Hull girder loads (i.e. vertical and horizontal bending moments).
- Dynamic wave pressures.
- Dynamic pressure from cargo.

The load values are based on Rule parameters corresponding to the loading conditions, e.g. *GM*, C_B, and the applicable draughts at amidships.

The simultaneously occurring dynamic loads are accounted for by combining the stresses due to the various dynamic load components. The stress combination procedure is given in Ch 9.

Load scenarios and corresponding rule requirements *Table 1*

Operation	Load type	Design load scenario	Acceptance criteria
Seagoing operations			
Transit	Static and dynamic loads in heavy weather	S + D	AC-SD
	Impact loads in heavy weather	Impact (I)	AC-I
	Internal sloshing loads	Sloshing (SL)	AC-S
	Cyclic wave loads	Fatigue (F)	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	S + D	AC-SD
Harbour and sheltered operations			
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	S	AC-S
Tank testing	Typical maximum loads during tank testing operations	S	AC-S
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	S	AC-S
Accidental condition			
Flooded conditions	Typically maximum loads on internal watertight subdivision structure in accidental flooded conditions	A	AC-SD AC-S

Acceptance criteria - prescriptive requirements **Table 2**

Acceptance criteria	Plate panels and local support members (1)		Primary supporting members(1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-S AC-SD	Permissible stress: Ch 6, Sec 4 Ch 6, Sec 5	Control of stiffness and proportions: Ch 8, Sec 2	Permissible stress: Ch 6, Sec 6 Pt 2, Ch 1, Sec 4 Pt 2, Ch 2, Sec 3	Control of stiffness and proportions: Ch 8, Sec 1 Ch 8, Sec 2 Pillar buckling	Permissible stress: Ch 5, Sec 1	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]

Acceptance criteria	Plate panels and local support members (1)		Primary supporting members(1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-I	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	N/A	N/A
(1) Refer to Ch 10 for Other structures and to Ch 11 for Superstructure, deckhouses and hull outfitting						

Acceptance criteria - FE analysis *Table 3*

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-S AC-SD	Permissible stress: Ch 7, Sec 2, [5]	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]	Permissible Von Mises stress: Ch 7, Sec 3, [6] Screening criteria: Ch 7, Sec 3, [3.3]

5.3.4 Structural response analysis

In general, the following approaches are applied for determination of the structural response to the applied design load combinations.

a) Beam theory:
   - Used for prescriptive requirements.

b) FE analysis:
   - Coarse mesh for cargo hold model.
   - Fine mesh for local models.
   - Very fine mesh for fatigue assessment.

5.4 *Acceptance criteria*

5.4.1 General

The acceptance criteria are categorised into three acceptance criteria sets. These are explained below and shown in Table 2 and Table 3. The specific acceptance criteria set that is applied in the rule requirements is dependent on the probability level of the characteristic combined load.

The acceptance criteria set AC-S is applied for the static design load combinations, and for the sloshing design loads. The allowable stress for such loads is lower than that for an extreme load to take into account effects of:

- Repeated yield.
- Allowance for some dynamics.
- Margins for some selected limited operational mistakes.

The acceptance criteria set AC-SD is applied for the S+D design load combinations where considered loads are extreme loads with a low probability of occurrence.

The acceptance criteria set AC-I is typically applied for impact loads, such as bottom slamming and bow impact loads.

5.4.2 *Acceptance criteria*

The specific acceptance criteria applied in the working stress design requirements are given in the detailed

Rule requirements in Pt 1, Ch 5 to Ch 8, Ch 10, Ch 11 and Pt 2, Ch 1 and Ch 2.

To provide a general informational summary overview of the acceptance criteria, refer to Table 2 and Table 3 below for the different design load scenarios covered by these Rules for the yield and buckling failure modes. For the yield criteria the permissible stress is proportional to the specified minimum yield stress of the material. For the buckling failure mode, the acceptance criteria are based on the control of stiffness and proportions as well as on the buckling utilisation factor.

5.5 *Design verification*

5.5.1 Design verification – hull girder ultimate strength

The requirements for the ultimate strength of the hull girder are based on a Partial Safety Factor (PSF) method. A safety factor is assigned to each of the basic variables, the still water bending moment, wave bending moment and ultimate capacity. The safety factors were determined using a structural reliability assessment approach, the long-term load history distribution of the wave bending moment was derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

The purpose of the hull girder ultimate strength verification is to demonstrate that one of the most critical failure modes of a ship is controlled.

5.5.2 *Design verification – global finite element analysis*

The global finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements to better consider the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy.

A linear elastic three dimensional finite element analysis of the cargo region (a FE model length of three holds is required) is carried out to assess and verify the structural response of the proposed hull girder and primary supporting members and assist in specifying the scantling requirements for the primary supporting members. The purpose with the finite element analysis is to verify that the stresses and buckling capability of the primary supporting members are within acceptable limits for the applied design loads.

5.5.3 *Design verification – fatigue assessment*

The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A simplified fatigue requirement is applied to details such as end connections of longitudinal stiffeners using stress concentration factors (SCF) to account the actual detail geometry. A fatigue assessment procedure using finite element analysis for determining the actual hot spot stress of the geometric detail is applied to selected details. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

5.5.4 *Relationship between prescriptive scantling requirements and FE analysis*

The scantlings defined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as FE analysis, unless explicitly stated.

Section 3 VERIFICATION OF COMPLIANCE

1 GENERAL

1.1 Newbuilding

1.1.1

For newbuildings, the plans and documents submitted for approval, as indicated in [2], are to comply with applicable requirements in these Rules, taking account of the relevant criteria, such as additional service features and classification notations assigned to the ship or the ship length.

1.1.2

When a ship is surveyed by the Society during construction, the Society:

- Approves the plans and documentation submitted as required by the Rules.
- Proceeds with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works.
- Carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the Rule requirements in relation to the approved drawings.
- Attends tests and trials provided for in the Rules.
- Assigns the classification character of the Society's notation.

1.1.3

The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

ISC 1.1.3a The appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

1.1.4

As part of his/her interventions during ship's construction, the surveyor:

- Conducts an overall examination of the parts of the ship covered by the Rules.
- Examines the construction methods and procedures when required by the Rules.
- Checks selected items covered by the Rule requirements.
- Attends tests and trials where applicable and deemed necessary.

1.1.5

Through all stages of ship construction, it is the builder's responsibility to promptly inform the Society of modifications or departures from approved plans. The builder is to ensure that any deviations from the requirements of the Rules or approved plans are, in any case, accepted by the Society.

1.2 *Ships in service 1.2.1*

For ships in service, the requirements in Ch 13 are to be complied with.

2 DOCUMENTS TO BE SUBMITTED

2.1 Documentation and data requirements

2.1.1 Loading information

Loading information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations is to be provided on board the ship. The loading information is to include an approved loading manual and loading instrument complying with the requirements given in Ch 1, Sec 5.

2.1.2 *Calculation data and results*

Where calculations have been carried out in accordance with the procedures given in the Rules, one copy of the following is to be submitted for information as applicable:

a) Reference to the calculation procedure and technical program used.
b) A description of the structural modelling.
c) A summary of the analysed parameter including properties and boundary conditions for direct analysis, when applicable.
d) Details of the loading conditions and the means of applying loads for direct analysis, when applicable.
e) A comprehensive summary of calculation results.
f) Sample calculations where appropriate.

The responsibility for error free specification and input of program data and the subsequent correct transposal of output resides with the designer.

Reference is made to Ch 7, Sec 1, [4.1] for required reporting of finite element analysis.

2.2 *Submission of plans and supporting calculations*

2.2.1 Plans and supporting calculations are to be submitted for approval

For the application of these Rules, the plans and supporting calculations to be submitted to the Society for approval are listed in Table 1.

Plans are to be submitted electronically or physically. When physically submitted plans are to be submitted in triplicate, with one copy necessary for supporting documents and calculations. In addition, the Society may request the submission of information, other plans and documents deemed necessary for the review of the design.

Structural plans are to show scantling, details of connection of the various parts and are to specify the design materials including, in general, their grades, manufacturing processes, welding procedures and heat treatments, and are to include information related to the renewal thickness as specified in Ch 13.

For welding requirements, see Ch 12, Sec 2 and Ch 12, Sec 3.

In case there are deviations from the design basis, then these are to be documented and submitted to the Society.

Plans and supporting calculation to be submitted for approval *Table 1*

Plan or supporting calculation	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, Wash bulkheads Standard construction details	Class characteristics Ship's main dimensions Minimum ballast draught Frame spacing Maximum service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures Welding
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	-
Aft part structure	-
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and RPM of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers and hatch coamings	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end

Plan or supporting calculation	Containing also information on
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	-
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	-
Scuppers and sanitary discharges	-
Mooring and towing arrangement	-
Supporting structure and foundations for shipboard fittings associated with mooring and towing operations	Design loads and directions of load actions, rated pull and holding load for mooring winches Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for mooring winches Material specifications and welding
Supporting structure and foundations for windlasses and chain stoppers	Design loads and directions of load actions Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for windlasses Material specifications and welding
Stern frame or sternpost, sterntube Propeller shaft boss and brackets (1)	-
Plan of watertight doors and scheme of relevant closing devices	Closing devices Electrical diagrams of power control and position indication circuits
Plan of weathertight or outer doors and hatchways	-
Supporting structure for lifting appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Maximum sea state in offshore operation, if any Connections to the hull structures
Supporting structure for life saving appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Connections to the hull structure
Sea chests, stabiliser recesses, etc	-
Plan of access to and escape from spaces	-
Plan of ventilation including ventilators and tank vents	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Anchoring arrangement	-

Plan or supporting calculation	Containing also information on
Hawse pipes	-
Loading manual and/or trim and stability booklet	-
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.	

2.2.2 *Plans to be submitted for information*

In addition to those in [2.2.1], the following plans are to be submitted to the Society for information:

a) General arrangement.
b) Capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks.
c) Lines plan, when deemed necessary by the Society.
d) Hydrostatic curves.
e) Lightweight distribution.
f) Docking plan.
g) Arrangement of lifting appliances.
h) Plan of manholes.

2.2.3 *Plans and instruments to be supplied onboard the ship*

As a minimum, the following plans and instrument are to be supplied onboard:

a) One copy of the following plans indicating the newbuilding and renewal thickness for each structural item is to be supplied onboard the ship: plans of midship sections, construction profiles, shell expansion, transverse bulkheads, aft and fore part structures, machinery space structures
One copy of the following plans indicating the newbuilding thickness for each structural item is to be supplied onboard the ship: plans of superstructures deckhouses and casing
b) One copy of the final approved loading manual, see [2.1.1].
c) One copy of the final approved loading instrument, see [2.1.1].
d) Welding.
e) Details of the extent and location of higher tensile steel together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.
f) Details and information on use of special materials, such as an aluminium alloy, used in the hull construction.
g) Towing and mooring arrangements plan.
h) Structural access manual.
i) Structural details for which post weld treatment methods are applied, showing the description of the details and their locations.

Other plans or instrument may be required by the Society.

ISC 2.2.3a For other plans and documents available on board which are to be submitted, see Appendix 1, Chapter 4, PART ONE of the Rules.

3 SCOPE OF APPROVAL

3.1 General

3.1.1

The attention of owners, designers and builders is directed to the regulations of international, national, canal, and other authorities dealing with those requirements which may affect structural aspects, in addition to or in excess of the classification requirements.

3.1.2

The documentation, plans and data requirements specified in [2] are to be submitted. The Society is to review such documentation to verify compliance with the requirements.

3.1.3
An appropriate term to indicate that the plans, reports or documents have been reviewed for compliance with these Rules is to be used according to the procedures of the Society.

ISC 3.1.3a Relevant procedures are to comply with the requirements of Section 5 Submission and Examination of Plans, Chapter 2, PART ONE of the Rules.

3.2 *Requirements of international and national regulations*

3.2.1 Responsibility

It is the responsibility of the designer to ensure that the design complies with the national and international regulations applicable to the ship.
The Society is not responsible for assessing compliance with international and national regulations as part of the general classification process. However, the Society may enter into an agreement with the flag administration of the ship under which they are explicitly instructed to review and approve a ship design for compliance with specified regulations.

4 *WORKMANSHIP*

4.1 Requirements to be complied with by the manufacturer

4.1.1
The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes and structural components. The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of the supervisory and control personnel in charge of the project.

4.2 *Quality control*

4.2.1
As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to verify that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.
Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally unpainted condition and enabling proper access for inspection.
The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

5 *STRUCTURAL DETAILS*

5.1 Details in manufacturing documents

5.1.1
Significant details concerning quality and functional ability of the component concerned are to be entered in the manufacturing documents (e.g. workshop drawing). This includes not only scantlings but, where relevant, such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. When a standard is used (works or national standard), it is to be submitted to the Society. For weld joint details, see Ch 12, Sec 2.
If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component is doubtful, the Society may require appropriate improvements to be submitted by the manufacturer. This includes the provision of supplementary or additional parts (for example, reinforcements) even if these were not required at the time of plan approval.

6 EQUIVALENCE PROCEDURES

6.1 Rule applications

6.1.1
These Rules apply to ships of normal form, proportions, speed and structural arrangements. Relevant design parameters defining the assumptions made are given in Ch 1, Sec 2, [3].

6.1.2
Special consideration is to be given to the application of the Rules incorporating design parameters which are outside the design basis as specified in Ch 1, Sec 2, [3], for example, increased fatigue life.

ISC 6.1.2a The procedure for assessing the alternative methods used in hull structural design should be followed in accordance with the requirements in ISC Appendix D of PART 9-1.

6.2 *Novel designs*

6.2.1
Ships of novel design, i.e. those of unusual form, proportions, speed and structural arrangements outside those specified in Ch 1, Sec 2, [3.2], are specially considered according to the contents of [6.2.2] to [6.2.4].

6.2.2
Information is to be submitted to the Society to demonstrate that the structural safety of the novel design is at least equivalent to that intended by the Rules.

6.2.3
In such cases, the Society is to be contacted at an early stage in the design process to establish the applicability of the Rules and additional information required for submission.

6.2.4
Dependent on the nature of the deviation, a systematic review may be required to document equivalence with the Rules.

6.3 *Alternative calculation methods 6.3.1*

Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantling and arrangements are of at least equivalent strength to those derived using the Rules.

Section 4 SYMBOLS AND DEFINITIONS

1 PRIMARY SYMBOLS AND UNITS

1.1 General

1.1.1

Unless otherwise specified, the general symbols and their units used in these Rules are those defined in Table 1.

Primary symbols *Table 1*

Symbol	Meaning	Units
A	Area	m^2
	Sectional area of stiffeners and primary members	cm^2
C	Coefficient	-
F	Force and concentrated loads	kN
I	Hull girder inertia	m^4
	Inertia of stiffeners and primary members	cm^4
M	Bending moment	kNm
M	Mass	t
P	Pressure	kN/m^2
Q	Shear force	kN
T	Draught of ship, see [3.1.5]	m
Z	Hull girder section modulus	m^3
	Section modulus of stiffeners and primary supporting members	cm^3
a_i	Acceleration for the effect 'i'	m/s^2
b	Width of attached plating	mm
	Width of face plate of stiffeners and primary supporting members	mm
g	Gravity acceleration, taken equal to 9.81 m/s2	m/s^2
h	Height	m
	Web height of stiffeners and primary supporting members	mm
l	Length/span of stiffeners and primary supporting members	m
n	Number of items	-
r	Radius	mm
	Radius of curvature of plating or bilge radius	mm
t	Thickness	mm
x	*X* coordinate along longitudinal axis, see [3.6]	m
y	*Y* coordinate along transverse axis, see [3.6]	m
z	*Z* coordinate along vertical axis, see [3.6]	m
η	Permissible utilisation factor (usage factor)	-
γ	Safety factor	-
δ	Deflection/displacement	mm
θ	Angle	deg
ρ	Density of seawater, taken equal to 1.025 t/m3	t/m^3

Symbol	Meaning	Units
σ	Normal stress	N/mm^2
τ	Shear stress	N/mm^2

2 *SYMBOLS*

2.1 Ship's main data

2.1.1

Unless otherwise specified, symbols regarding ship's main data and their units used in these Rules are those defined in Table 2.

Ship's main data **Table 2**

Symbol	Meaning	Units
L	Rule length	m
L_{LL}	Freeboard length	m
L_{PP}	Length between perpendiculars	m
L_0	Rule length, L, but not to be taken less than 110 m	m
L_1	Rule length, L, but need not be taken greater than 250 m	m
L_2	Rule length, L, but need not be taken greater than 300 m	m
B	Moulded breadth of ship	m
D	Moulded depth of ship	m
T	Moulded draught	m
T_{SC}	Scantling draught	m
T_{BAL}	Ballast draught (minimum midship)	m
T_{BAL-H}	Heavy ballast draught at midship	m
T_{BAL-E}	Emergency ballast draught or gale ballast draught at midship	m
T_{LC}	Midship draught at considered loading condition	m
T_{F-f}, T_{F-e}	Minimum draught at forward perpendicular for bottom slamming, with respectively all ballast tanks full or with any tank empty in bottom slamming area	m
Δ	Moulded displacement at draught T_{SC}	t
C_B	Block coefficient at draught T_{SC}	-
V	Maximum service speed	knot
x, y, z	X,Y,Z coordinates of the calculation point with respect to the reference coordinate system	m

2.2 Materials

2.2.1

Unless otherwise specified, symbols regarding materials and their units used in these Rules are those defined in Table 3.

Materials *Table 3*

Symbol	Meaning	Units
E	Young's modulus, see Ch 3, Sec 1, [2]	N/mm^2
G	Shear modulus, $G = \frac{E}{2(1+\nu)}$	N/mm^2

Symbol	Meaning	Units
R_{eH}	Specified minimum yield stress, see Ch 3, Sec 1, [2]	N/mm^2
τ_{eH}	Specified shear yield stress, $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm^2
ν	Poisson's ratio, see Ch 3, Sec 1, [2]	-
k	Material factor, see Ch 3, Sec 1, [2]	-
R_m	Specified minimum tensile strength, see Ch 3, Sec 1, [2]	N/mm^2
R_Y	Nominal yield stress, taken equal to 235/k	N/mm^2

2.3 *Loads*

2.3.1

Unless otherwise specified, symbols regarding loads and their units used in these Rules are those defined in Table 4.

Loads *Table 4*

Symbol	Meaning	Units
C_w	Wave coefficient	-
T_θ	Roll period	s
θ	Roll angle	deg
T_φ	Pitch period	s
φ	Pitch angle	deg
a_o	Common acceleration parameter	-
a_z	Vertical acceleration	m/s^2
a_y	Transverse acceleration	m/s^2
a_x	Longitudinal acceleration	m/s^2
f_p	Probability factor	-
k_r	Roll amplitude of gyration	m
GM	Metacentric height	m
λ	Wave length	m
S	Static load case	-
S+D	Dynamic load case	-
P_{ex}	Total sea pressure, see Ch 4, Sec 5, [1.1]	kN/m^2
P_{in}	Total internal pressure due to liquid, see Ch 4, Sec 6, [1], or due to dry bulk cargo, see Ch 4, Sec 6, [2.4.1]	kN/m^2
P_s	Static sea pressure	kN/m^2
P_{ls}	Static tank pressure	kN/m^2
P_w	Dynamic wave pressure	kN/m^2
P_{ld}	Dynamic tank pressure	kN/m^2
P_D	Green sea deck pressure	kN/m^2
$P_{slh\text{-}j}$	Sloshing pressure, j=direction	kN/m^2
P_{dl}	Total pressure due to distributed load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.2]	kN/m^2

Symbol	Meaning	Units
P_{SL}	Bottom slamming pressure	kN/m^2
P_{FB}	Bow impact pressure	kN/m^2
P_{fs}	Static pressure in flooded conditions	kN/m^2
P_{fd}	Dynamic pressure in flooded conditions	kN/m^2
P_{ST}	Tank testing pressure (static)	kN/m^2
F_U	Total force due to concentrated load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.3]	kN
$M_{sw\text{-}j}$	Vertical still water bending moment, $j = h, s, p$ (hog, sag, harbour)	kNm
Q_{sw}	Vertical still water shear force	kN
$M_{wv\text{-}j}$	Vertical wave bending moment, $j = h, s$ (hog, sag)	kNm
Q_{wv}	Vertical wave shear force	kN
M_{wt}	Torsional wave moment	kNm
M_{wh}	Horizontal wave bending moment	kNm

2.4 *Scantlings*

2.4.1

Unless otherwise specified, symbols regarding scantlings and their units used in these Rules are those defined in Table 5.

Scantlings *Table 5*

Symbol	Meaning	Units
$I_{y\text{-}n50}$	Net vertical moment of inertia of hull girder	m^4
$I_{z\text{-}n50}$	Net horizontal moment of inertia of hull girder	m^4
$Z_{D\text{-}n50}$, $Z_{B\text{-}n50}$	Net vertical hull girder section moduli, at deck and bottom respectively	m^3
z_n	Vertical distance from BL to horizontal neutral axis	m
a	Length of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
b	Breadth of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
s	Stiffener spacing (see Ch 3, Sec 7, [1.2.1])	mm
S	Primary supporting member spacing (see Ch 3, Sec 7, [1.2.2])	m
l	Span of stiffeners or primary supporting member (see Ch 3, Sec 7, [1])	m
l_b	Bracket arm length	m
t	Net thickness with full corrosion reduction	mm
t_{n50}	Net thickness with half corrosion reduction	mm
t_c	Corrosion addition	mm
t_{gr}	Gross thickness	mm
t_{as_built}	As built thickness	mm
t_{gr_off}	Gross thickness offered	mm
t_{gr_req}	Gross thickness required	mm
t_{off}	Net thickness offered	mm
t_{req}	Net thickness required	mm
t_{vol_add}	Thickness for voluntary addition	mm
t_{res}	Reserve thickness	mm

Symbol	Meaning	Units
t_{c1}, t_{c2}	Corrosion addition on each side of structural member	mm
h_w	Web height of stiffener or primary supporting member	mm
t_w	Web thickness of stiffener or primary supporting member	mm
b_f	Face plate width stiffener or primary supporting member	mm
h_{stf}	Height of stiffener	mm
t_f	Face plate/flange thickness of stiffener or primary supporting member	mm
t_p	Thickness of the plating attached to a stiffener or a primary supporting member	mm
b_{eff}	Effective breadth of attached plating, in bending, for yield and fatigue	mm
A_{eff} or $A_{eff\text{-}n50}$	Net sectional area of stiffeners or primary supporting members, with attached plating (of width *s*)	cm^2
A_{shr} or $A_{shr\text{-}n50}$	Net shear sectional area of stiffeners or primary supporting members	cm^2
I_p	Net polar moment of inertia of stiffener about its connection to plating	cm^4
I	Net moment of inertia of the stiffener, with attached shell plating, about its neutral axis parallel to the plating	cm^4
Z or Z_{n50}	Net section modulus of a stiffener or primary supporting member with attached plating (of breadth b_{eff})	cm^3

3 DEFINITIONS

3.1 Principal Particulars

3.1.1 *L*, Rule length

The Rule length *L* is the distance, in m, measured on the waterline at the scantling draught *TSC* from the forward side of the stem to the centre of the rudder stock. *L* is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the Rule length *L* is to be taken equal to 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships with unusual stem or stern arrangements, the Rule length is considered on a case-by-case basis.

ISC 3.1.1a For ships with unusual stem or stern arrangements, the Rule length L is 97% of the distance, in m, measured on the waterline at the scantling draught T_{SC} from the forward side of the stem to the after side of the stern frame.

3.1.2 *L_{LL}, freeboard length*

The freeboard length L_{LL}, in m, is to be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.

For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.

Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline), see Figure 1.

3.1.3 *Moulded breadth*

The moulded breadth *B* is the greatest moulded breadth, in m, measured amidships at the scantling draught, T_{SC}.

3.1.4 *Moulded depth*

D, the moulded depth, is the vertical distance, in m, amidships, from the moulded baseline to the

moulded deck line of the uppermost continuous deck measured at deck at side. On ships with a rounded gunwale, *D* is to be measured to the continuation of the moulded deck line.

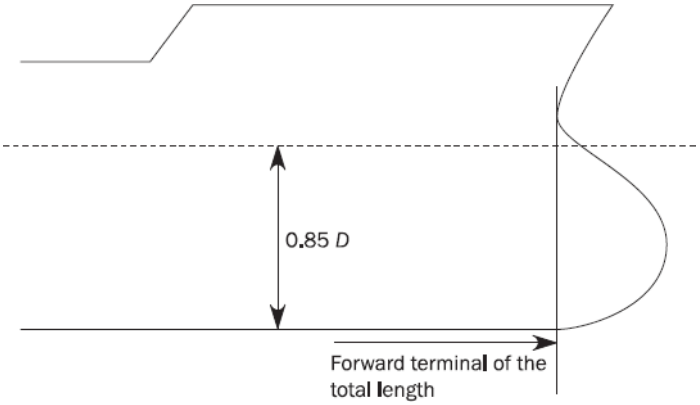


Figure 1 Concave stem contour

3.1.5 Draughts

T, the draught in m, is the summer load line draught for the ship in operation, measured from the moulded baseline at midship. Note this may be less than the maximum permissible summer load waterline draught.

T_{SC} is the scantling draught, in m, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught T_{SC} is to be not less than that corresponding to the assigned freeboard. The draught of ships to which timber freeboards are assigned corresponds to the loading condition of timber, and the requirements of the Society are to be applied to this draught.

T_{BAL} is the minimum design normal ballast draught amidships, in m, at which the strength requirements for the scantlings of the ship are met. This normal ballast draught is the minimum draught of ballast conditions including ballast water exchange operation. If any, for any ballast conditions in the loading manual including both departure and arrival conditions.

$T_{BAL\text{-}H}$ is the minimum design heavy ballast draught, in m, at which the strength requirements for the scantlings of the ship are met. This heavy ballast draught is to be considered for ships having heavy ballast condition.

3.1.6 *Moulded displacement*

Moulded displacement, in t, corresponds to the underwater volume of the ship, at a draught, in seawater with a density of 1.025 t/m^3.

3.1.7 *Maximum service speed*

V, the maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

3.1.8 *Block coefficient*

C_B, the block coefficient at the draught, T_{SC} is defined in the following equation:

$$C_B = \frac{\Delta}{1.025LBT_{SC}}$$

where:

Δ: Moulded displacement of the ship at draught T_{SC}.

3.1.9 *Lightweight*

The lightweight is the ship displacement, in t, complete in all respects, but without cargo, consumable stores, crew and their effects, and without any liquids on board except that machinery and piping fluids, such as lubricants and hydraulics, are at operating levels.

3.1.10 *Deadweight*

The deadweight DWT is the difference, in t, between the displacement, at the summer draught in

seawater of density $\rho = 1.025$ t/m^3, and the lightweight.

3.1.11 *Fore end*
The fore end (FE) of the rule length *L*, see Figure 2, is the perpendicular to the scantling draught waterline at the forward side of the stem.

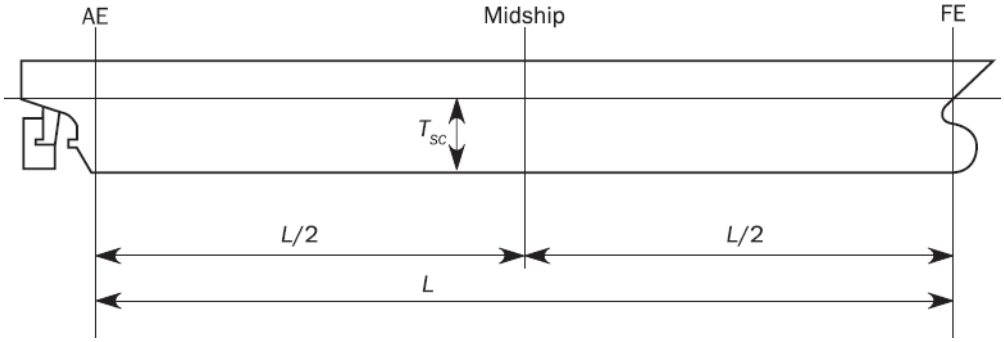


Figure 2 Ends and midship

3.1.12 Aft end
The aft end (AE) of the rule length *L*, see Figure 2, is the perpendicular to the scantling draught waterline at a distance *L* aft of the fore end.

3.1.13 *Midship*
The midship is the perpendicular to the scantling draught waterline at a distance 0.5 *L* aft of the fore end.

3.1.14 *Midship part*
The midship part of a ship is the part extending 0.4 *L* amidships, unless otherwise specified.

3.1.15 *Forward freeboard perpendicular*
The forward freeboard perpendicular, FP_{LL}, is to be taken at the forward end of the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured.

3.1.16 *After freeboard perpendicular*
The after freeboard perpendicular, AP_{LL}, is to be taken at the aft end of the length L_{LL}.

3.2 *Position 1 and Position 2*
3.2.1 Position 1
Position 1 includes:
- Exposed freeboard and raised quarter decks.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL}.

3.2.2 *Position 2*
Position 2 includes:
- Exposed superstructure decks situated aft of 0.25 L_{LL} from FP_{LL} and located at least one standard height of superstructure above the freeboard deck.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL} and located at least two standard heights of superstructure above the freeboard deck.

3.3 *Standard height of superstructure*
3.3.1
The standard height of superstructure is defined in Table 6.

Standard height of superstructure *Table 6*

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} \leq 125$	$0.3 + 0.012\ L_{LL}$	$1.05 + 0.01\ L_{LL}$

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
L_{LL} > 125	1.80	2.30

3.3.2
A tier is defined as a measure of the extent of a deckhouse. A deckhouse tier consists of a deck and external bulkheads. In general, the first tier is the tier situated on the freeboard deck.

3.4 *Type A and Type B freeboard ships*

3.4.1 Type A ship

Type A ship is one which:

- Is designed to carry only liquid cargoes in bulk.
- Has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material.
- Has low permeability of loaded cargo compartments.

Type A ship is to be assigned a freeboard following the requirements specified in the ICLL.

3.4.2 *Type B ship*

All ships which do not come within the provisions regarding Type A ships stated in [3.4.1] are to be considered as Type B ships.
Type B ship is to be assigned a freeboard following the requirements specified in ICLL.

3.4.3 *Type B-60 ship*

Type B-60 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 60% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.4.4 *Type B-100 ship*

Type B-100 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 100% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.5 *Operation definition*

3.5.1 Multiport

Multiport corresponds to short voyage with loading and unloading in multiple ports.

3.5.2 *Sheltered water*

Sheltered waters are generally calm stretches of water when the wind force does not exceed 6 Beaufort scale, i.e. harbours, estuaries, roadsteads, bays, lagoons.

3.6 *Reference coordinate system*

3.6.1

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system, see Figure 3:
Origin : At the intersection among the longitudinal plane of symmetry of ship, the aft end of *L* and the baseline.
X axis : Longitudinal axis, positive forwards.
Y axis : Transverse axis, positive towards portside.
Z axi : Vertical axis, positive upwards.

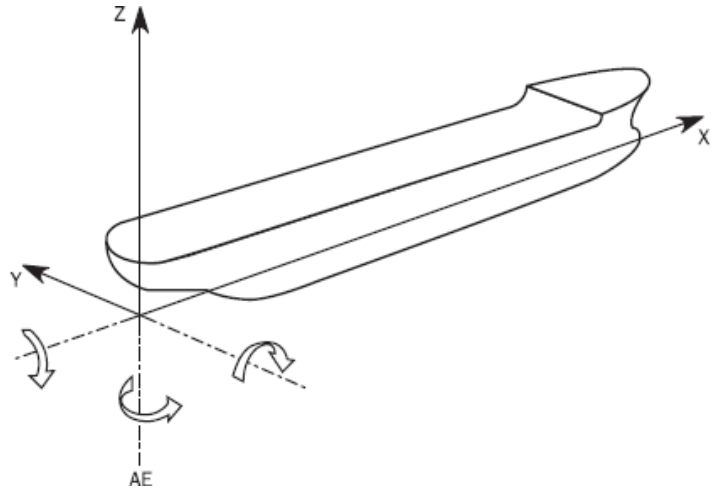


Figure 3 Reference coordinate system

3.7 Naming convention

3.7.1 Structural nomenclature

Figure 4 to Figure 8 show the common structural nomenclature used within these Rules.

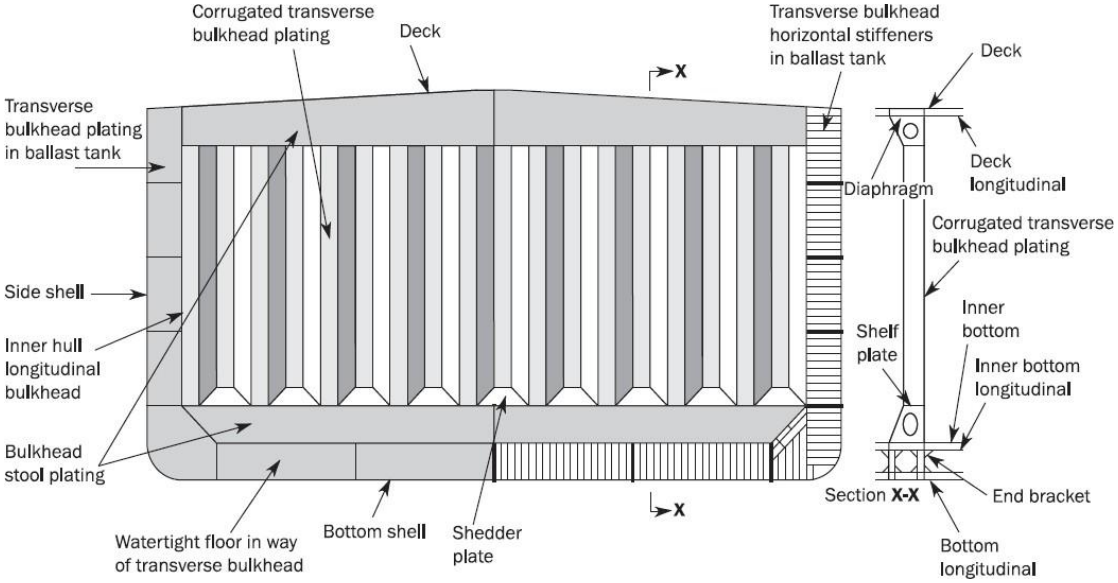


Figure 4 Corrugated transverse bulkhead of double hull tanker

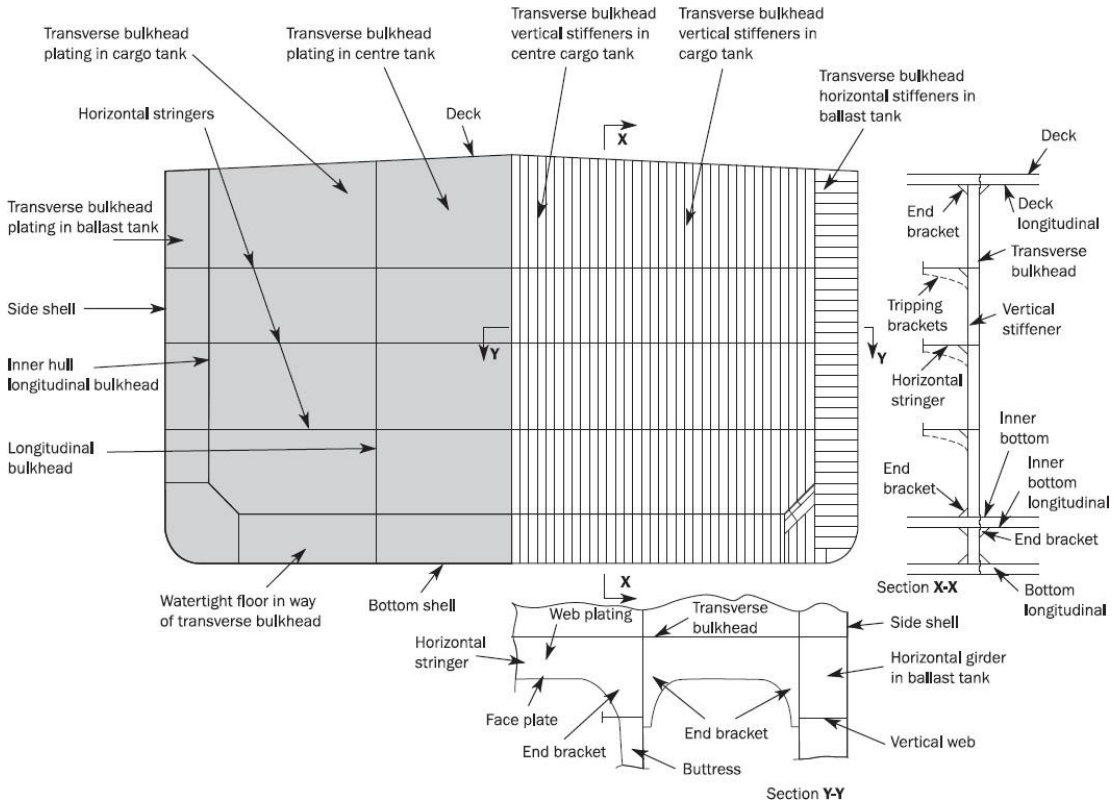


Figure 5 Transverse bulkhead of double hull tanker

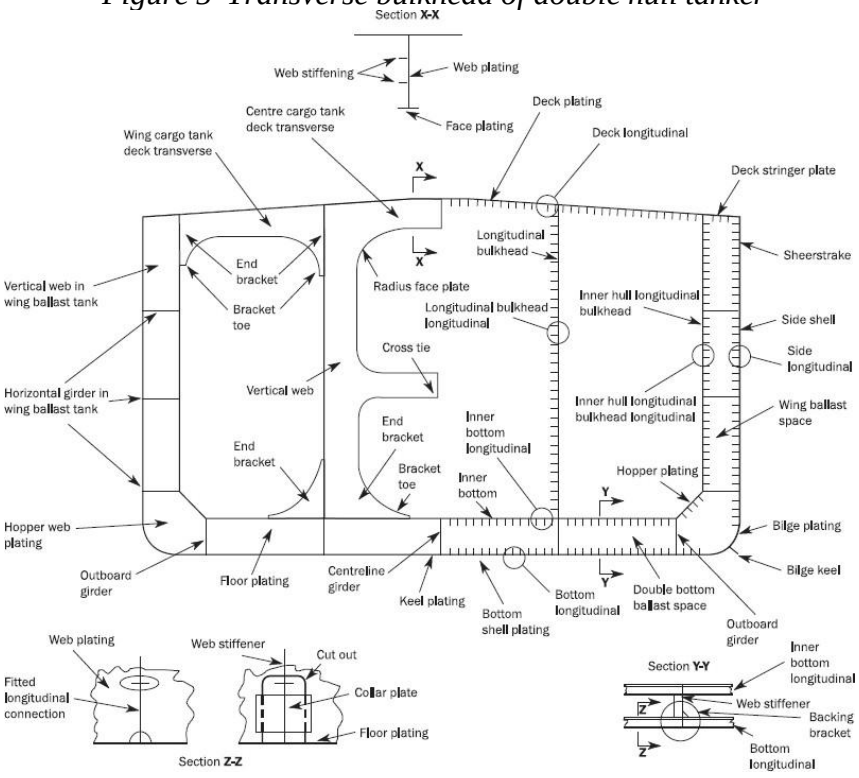


Figure 6 Mid cargo hold transverse section of double hull tanker

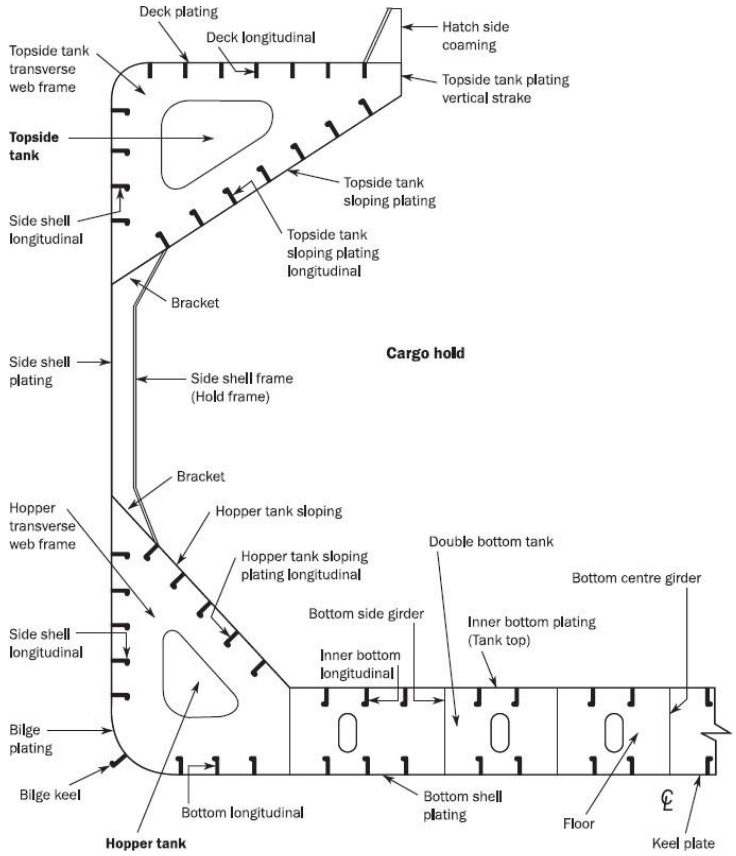


Figure 7 Mid cargo hold transverse section of single side bulk carrier

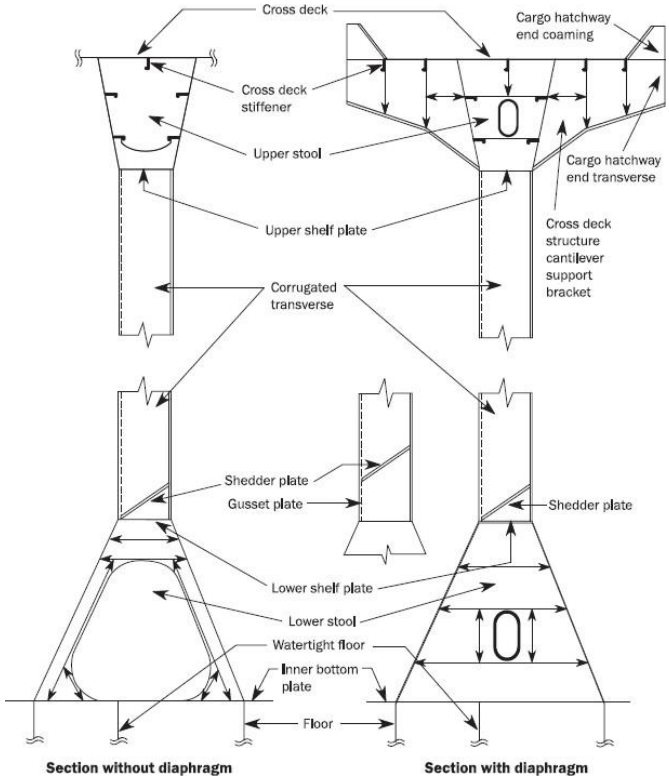


Figure 8 Transverse bulkhead of bulk carrier

3.8 Glossary

3.8.1 Definitions of term

Definition of terms *Table 7*

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew.
Accommodation ladder	A portable set of steps on a ship's side for people boarding from small boats or from a pier.
Aft peak	The area aft of the aft peak bulkhead.
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern.
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead.
Anchor	A device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current, usually made of heavy casting or casting.
Ballast tank	A compartment used for the storage of water ballast.
Bay	The area between adjacent transverse frames or transverse bulkheads.
Bilge hopper tank	The tank used for ballast or for stability when carrying certain cargoes in bulk carriers.
Bilge keel	A piece of plate set perpendicular to a ship's shell along the bilges to reduce the rolling motion.
Bilge plating	The bilge plating is the curved plating between the bottom shell and side shell. It is to be taken as follows: Within the cylindrical part of the ship: From the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge, Outside the cylindrical part of the ship: From the start of the curvature at the lower turn of the bilge on the bottom to the lesser of: ● A point on the side shell located 0.2*D* above the baseline/local centreline elevation. ● The end of the curvature at the upper turn of the bilge.
Bilge strake	The lower strake of bilge plating.
Boss	The boss of the propeller is the central part to which propeller blades are attached and through which the shaft end passes.
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate.
Bow	The structural arrangement and form of the forward end of the ship.
Bower anchor	An anchor carried at the bow of the ship.
Bracket	An extra structural component used to increase the strength of a joint between two structural members.
Bracket toe	The narrow end of a tapered bracket.
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow.
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem.
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered.
Buckling panel	Elementary plate panel considered for the buckling analysis.
Builder	The party contracted by the owner to build a ship in compliance with the specifications including Rules.
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange.

Terms	Definition
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments.
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried.
Bulkhead stool	The lower or upper base of a corrugated bulkhead.
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders.
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s).
Bunker	A compartment for the storage of fuel oil used by the ship's machinery.
Cable	A rope or chain attached to the anchor.
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship.
Cargo hold region	See Ch 1, Sec 1, [2.4.3].
Cargo hold	Generic term for spaces intended to carry cargo, liquid or dry bulk.
Cargo tank	Tank carrying cargoes
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks.
Carlings	A stiffening member used to supplement the regular stiffening arrangement.
Casing	The covering or bulkhead around or about any space for protection.
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments.
Centreline girder	A longitudinal member located on the centreline of the ship.
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain.
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker.
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass.
Coaming	The vertical boundary structure of a hatch or skylight.
Cofferdams	See Ch 2, Sec 3, [1].
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web.
Collision bulkhead	The foremost main transverse watertight bulkhead.
Companionway	A weathertight entrance leading from a ship's deck to spaces below.
Compartment	An internal space bounded by bulkheads or plating.
Continually manned space	A space in which the continuous or prolonged presence of seafarers is necessary for normal operational periods. This includes spaces routinely occupied for a period of 20 minutes or more during normal operational periods.
Corrugated bulkhead	A bulkhead including corrugations and usually fitted with lower and upper stools.
Corrugation	Plating arranged in a corrugated fashion, shedder and gusset plates excluded.
Cross deck	The area between cargo hatches.

Terms	Definition
Cross ties	Large transverse structural members joining longitudinal bulkheads or joining a longitudinal bulkhead with double side structures and used to support them against hydrostatic and hydrodynamic loads.
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment.
Deckhouse	See Ch 1, Sec 1, [2.4.6].
Deck structure	The deck plating with stiffeners, girders and supporting pillars.
Deck transverse	Transverse PSM at the deck.
Deep tank	Any tank which extends between two decks or the shell/inner bottom and the deck above or higher.
Designer	A party who creates documentation submitted to the Society necessary for approval or for information. The designer can be the builder or a party contracted by the builder or owner to create this documentation.
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking.
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating.
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener.
Double skin member	Double skin member is defined as a structural member where the idealised beam comprises webs, with top and bottom flanges formed by attached plating.
Duct keel	A keel built of plates in box form. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks and/or ballast tanks.
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances.
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room.
EPP	Elementary plate panel, the smallest plate element surrounded by structural members, such as stiffeners, PSM, bulkheads, etc.
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface.
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface.
Flat bar	A stiffener comprised only of a web.
Floor	A bottom transverse member.
Forecastle	A short superstructure situated at the bow.
Fore peak	The area of the ship forward of the collision bulkhead.
Fore peak deck	A short raised deck extending aft from the bow of the ship.
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings.
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard.

Terms	Definition
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop.
Girder	A collective term for primary supporting structural members.
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing.
Gunwale	The upper edge of the ship's sides.
Gusset	A plate, usually fitted to distribute forces at a strength connection between two structural members.
Hatch cover	A cover fitted over a hatchway to prevent the ingress of water into the ship's hold.
Hatchways	Openings, generally rectangular, in a ship's deck affording access into the compartment below.
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe.
Hawser	Large steel wire or fibre rope used for towing or mooring.
Hopper plating	Plating running the length of a compartment sloping between the inner bottom and vertical portion of inner hull longitudinal bulkhead.
HP	Bulb profile in accordance with the Holland profile standard.
IACS	International Association of Classification Societies
ICLL	IMO International Convention on Load Lines, 1966, as amended.
IMO	International Maritime Organisation
Independent tank	A self supporting tank.
Inner hull	The innermost plating forming a second layer to the hull of the ship.
Intercostal	Non-continuous member between stiffeners or PSM.
JIS	Japanese industrial standard.
Keel	The main structural member or backbone of a ship running longitudinally along the centreline of the bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell.
Keel line	Keel line is the line parallel to the slope of the keel intersecting the top of the keel at amidships.
Knuckle	A discontinuity in a structural member.
Lightening hole	A hole cut in a structural member to reduce its weight.
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting.
Local support members	Local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams.
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship.
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks.
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders.
Manhole	A round or oval hole cut in decks, tanks, etc, for the purpose of providing access.

Terms	Definition
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom.
MARPOL	IMO International Convention for the Prevention of Pollution from Ships, 1973 and Protocol of 1978, as amended.
Mid-hold	Middle hold(s) of the three cargo hold length FE model as defined in Pt 1, Ch 7, Sec 2, [1.2.2]
Normally unmanned space	A space not normally manned (without the continuous or prolonged presence of seafarers) during normal operational periods. This includes spaces routinely occupied for a period of less than 20 minutes during normal operational periods.
Notch	A discontinuity in a structural member caused by welding.
Oil fuel tank	A tank used for the storage of fuel oil.
Outer shell	Same as shell envelope.
Owner	The party that has assumed all duties and responsibilities for registration and operation of the ship and who on assuming such responsibilities has agreed to take over all the duties and responsibilities on delivery of the ship from the builder with valid certificates prepared for the owner.
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead.
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks.
Plate panel	Unstiffened plate surrounded and supported by structural members, such as stiffeners, PSM, bulkheads, etc. See also EPP.
Plating	Sheet of steel supported by stiffeners, primary supporting members or bulkheads.
Poop	The space below an enclosed superstructure at the extreme aft end of a ship.
Poop deck	The first deck above the shelter deck at the aft end of a ship.
Primary supporting members PSM	Members of the beam, girder or stringer type which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.
Propeller post	The forward post of stern frame, which is bored for propeller shaft.
Rudder post	After post of stern frame to which the rudder is hung (also called stern post).
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam.
Scarfing bracket	A bracket used between two offset structural items.
Scantlings	The physical dimensions of a structural item.
Scupper	Any opening for carrying off water from a deck, either directly or through piping.
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment.
Shedder plates	Slanted plates that are fitted to minimize pocketing of residual cargo in way of corrugated bulkheads.
Sheer strake	The top strake of a ship's side shell plating.
Shelf plate	A horizontal plate located on the top of a bulkhead stool.
Shell envelope plating	The shell plating forming the effective hull girder exclusive of the strength deck plating.

Terms	Definition
Side frame	A vertical member attached to the side shell in bulk carriers.
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating.
Single skin member	A structural member where the idealised beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate.
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing.
SOLAS	IMO International Convention for the Safety of Life at Sea, 1974 as amended.
Spaces	Separate compartments including tanks.
Stay	Bulwark and hatch coaming brackets.
Stem	The piece of bar or plating at which a ship's outside plating terminates at the forward end.
Stern	The after end of the vessel.
Stern frame	The heavy strength members attached to the after end of a hull to form the ship's stern. It includes rudder post, propeller post, and aperture for the propeller.
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearing for the shafting. It may be water or oil lubricated.
Stiffener	A collective term for secondary supporting structural members.
Stool	A structure supporting tank bulkheads.
Strake	A course, or row, of shell, deck, bulkhead, or other plating.
Strength deck	The uppermost continuous deck.
Stringer	Horizontal girders linking vertical web frames.
Stringer plate	The outside strake of deck plating.
Superstructure	See Ch 1, Sec 1, [2.4.6].
SWL	Safe working load
Tank	Generic term for spaces intended to carry liquid, such as, seawater, fresh water, oil, liquid cargoes, FO, DO, etc.
Tank top	The horizontal plating forming the bottom of a cargo tank.
Towing pennant	A long rope which is used to effect the tow of a ship.
Topside tank	The tank that normally stretches along the length of the ship's side and occupies the upper corners of the cargo hold in bulk carriers.
Transom	The structural arrangement and form of the aft end of the ship.
Transverse ring	All transverse material appearing in a cross section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder.
Transverse web frame	The primary transverse girders which join the ships longitudinal structure.
Tripping bracket	A bracket used to strengthen a structural member under compression against torsional forces.
Trunk	A decked structure similar to a deckhouse, but not provided with a lower deck.
'Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks.
Ullage	The quantity represented by the unoccupied space in a tank.
Void	An enclosed empty space in a ship.

Terms	Definition
Wash bulkhead	A perforated or partial bulkhead in a tank.
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.
Weather deck	A deck or section of deck exposed to the elements which has means of closing weathertight, all hatches and openings.
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship.
Web	The section of a stiffening member attached perpendicular to the plated surface.
Web frame	Transverse PSM including deck transverse.
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load waterline.
Windlass	A winch for lifting and lowering the anchor chain.
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell.

Section 5 LOADING MANUAL AND LOADING INSTRUMENTS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1

This Section contains minimum requirements for loading guidance information.

1.1.2

An approved loading manual and an approved loading instrument are to be supplied onboard.

1.1.3

A ship may in actual operation be loaded differently from the loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

1.1.4

The requirements concerning the loading manual are given in [2] and those concerning the loading instruments in [3].

1.2 *Annual and class renewal survey 1.2.1*

At each annual and class renewal survey, it is to be checked that the approved loading manual is available onboard.

1.2.2

The loading instrument is to be checked for accuracy at regular intervals by the ship's master by applying test loading conditions.

1.2.3

At each class renewal survey this checking is to be done in the presence of the surveyor.

2 LOADING MANUALS

2.1 General requirements

2.1.1 Definition

The approved loading manual is to be based on the final data of the ship.

A loading manual is a document which describes:

- The loading conditions on which the design of the ship has been based for seagoing and harbour/sheltered water, including permissible limits of still water bending moment and shear force. The conditions specified in the ballast water exchanging procedure and dry docking procedure are to be included in the loading manual,
- The results of the calculations of still water bending moments, shear forces and where applicable limitations due to lateral loads,
- The allowable local loading for the structure (e.g. hatch covers, decks, double bottom, etc), where applicable,
- The relevant operational limitations.

2.1.2 *Condition of approval*

The approved loading manual is to be based on the final data of the ship.

Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading computer system to be updated and re-approved. However, new loading guidance and an updated loading manual need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

The loading manual is to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

2.1.3 *Loading conditions*

The loading manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, as defined in Ch 4, Sec 8.

The loading conditions common to both oil tankers and bulk carriers are listed in Ch 4, Sec 8, [2].

2.1.4 *Operational limitations*

The loading manual is to describe relevant operational limitations:

- Scantling draught,
- Design minimum ballast draught at midships,
- Design slamming ballast draught forward with forward double bottom ballast tanks filled,
- Design slamming ballast draught forward with any of the forward double bottom ballast tanks empty,
- Maximum allowable cargo density,
- Maximum cargo density in any loading condition in the Loading Manual,
- Maximum service speed,
- Envelope results and permissible limits of still water bending moments and shear forces.

The loading manual must indicate that bulk carriers cannot be operated in seagoing conditions with ballast cargo holds partially filled.

2.2 *Requirements specific to oil tankers 2.2.1*

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [3]. This requirement applies in addition to [2.1].

2.3 *Requirements specific to bulk carriers 2.3.1*

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [4]. This requirement applies in addition to [2.1].

2.3.2

The loading manual is to describe:

- Envelope results and permissible limits of still water bending moments and shear forces in the flooded conditions according to Ch 4, Sec 4,
- The cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual,
- Maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes,
- Maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual,
- Maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.3.3

The additional following loading conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

- Homogeneous light and heavy cargo loading conditions at maximum draught,
- Alternate light and heavy cargo loading conditions at maximum draught, where

applicable,

- Ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty,
- Short voyage conditions, i.e. the ship is loaded to maximum draught but with a limited amount of bunkers, where appropriate,
- Multiple port loading/unloading conditions,
- Deck cargo conditions, where applicable,
- Typical sequences for change of ballast at sea, where applicable,
- Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. Figure 1 contains, as guidance only, an example of a Loading Sequence Summary Form.

3 LOADING INSTRUMENT

3.1 General requirements

3.1.1 Definition

A loading computer system is a system, which is either analog or digital, by means of which it can be easily and quickly ascertained that, at specified read-out points, relevant operational limitations, such as the still water bending moments, shear forces, and lateral loads, where applicable, in any load or ballast condition do not exceed the specified permissible values.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument can not replace an approved loading manual.

3.1.2 *Conditions of approval of loading instruments*

The loading instrument is subject to approval based on the Rules of the individual Society. The approval is to include:

- Verification of type approval, if any,
- Verification that the final data of the ship has been used,
- Acceptance of number and position of read-out points,
- Acceptance of relevant limits for all read-out points,
- Checking of proper installation and operation of the instrument onboard, in accordance with agreed test conditions, and that a copy of the operation manual is available.

Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading instrument to be updated and re-approved. However, new loading guidance and an updated loading instrument need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

An operational manual is always to be provided for the loading instrument. The operation manual and the instrument output are to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

The operation of the loading instrument is to be verified upon installation. It is to be checked that the agreed test conditions and the operation manual for the instrument is available onboard.

ISC 3.1.2a The loading instruments are to comply with the requirements of Appendix 1, Chapter 2, PART TWO of ISC Rules for Classification of Sea-going Steel Ships.

3.2 *Requirements specific to bulk carriers*

3.2.1 General

For BC-A, BC-B and BC-C ships, the loading instrument is to ascertain as applicable:

- The mass of cargo and double bottom contents in way of each hold as a function of the

draught at mid- hold position,

- The mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds,
- That the still water bending moment and shear forces in the hold flooded conditions do not exceed the specified permissible values.

3.2.2 *Condition of approval*

For BC-A, BC-B and BC-C ships, the approval is to include, as applicable:

- Acceptance of hull girder bending moment limits for all read-out points,
- Acceptance of hull girder shear force limits for all read-out points,
- Acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught,
- Acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

4 LOADING SPECIFIC TO BULK CARRIERS

4.1 Guidance for loading/unloading sequences

4.1.1 Scope of application

The requirements given in [4] are applicable to bulk carriers having a freeboard length L_{LL} of 150 m or above.

4.1.2

The typical loading/unloading sequences are to be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

4.1.3

Typical loading and unloading sequences are to be prepared and submitted for approval by the builder.

4.1.4

The typical loading sequences as relevant are to include:

- Alternate light and heavy cargo load condition,
- Homogeneous light and heavy cargo load condition,
- Short voyage condition where the ship is loaded to maximum draught but with limited bunkers,
- Multiple port loading/unloading condition,
- Deck cargo condition,
- Block loading.

4.1.5

The loading/unloading sequences may be port specific or typical.

4.1.6

The sequence is to be built up step by step from commencement of cargo loading to reach full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local strength of each hold is to be considered.

4.1.7

For each loading condition, a summary of all steps is to be included. This summary is to highlight the essential information for each step, such as:

- How much cargo is filled in each hold during the different steps,
- How much ballast is discharged from each ballast tank during the different steps,
- The maximum still water bending moment and shear force at the end of each step,
- The ship’s trim and draught at the end of each step.

Figure 1 Loading Sequence Summary Form

Chapter 2 GENERAL ARRANGEMENT DESIGN

Section 1 GENERAL

1 GENERAL

1.1 General

1.1.1

This chapter covers the general structural arrangement requirements for the ship.

1.1.2

Arrangements for continually manned spaces are to include consideration of ventilation, lighting, noise and whole-body vibration in accordance with industry standards accepted by the Society. See also Sec 4, [1.1.1] to [1.1.3].

ISC 1.1.2a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

1.1.3

Arrangements for normally unmanned spaces are to include consideration of lighting and ventilation for periodic inspections, survey and maintenance in accordance with industry standards accepted by the Society. See also Sec 4,[1.1.1] to [1.1.5].

ISC 1.1.3a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

Section 2 SUBDIVISION ARRANGEMENT

1 WATERTIGHT BULKHEAD

ARRANGEMENT

1.1 Number and disposition of watertight bulkheads

1.1.1

All ships are to have at least the following transverse watertight bulkheads:

a) One collision bulkhead.
b) One aft peak bulkhead.
c) One bulkhead forward of the machinery space, and one bulkhead at the aft end of the machinery space which may be the aft peak bulkhead.

1.1.2

In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.3

In addition to the requirements of [1.1.1] and [1.1.2], the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of national regulations.

1.1.4

For bulk carriers with freeboard length L_{LL} less than 150 m not required to comply with subdivision requirements, bulkheads not less in number than indicated in Table 1 are to be fitted.

Number of bulkheads for bulk carriers with freeboard length L_{LL} less than 150 m Table 1

Freeboard length in m	Number of bulkheads for ships with aft machinery(1)
$90 \leq L_{LL} < 105$	4
$105 \leq L_{LL} < 120$	5
$120 \leq L_{LL} < 145$	6
$145 \leq L_{LL} < 150$	7
(1) Aft peak bulkhead and aft machinery bulkhead are the same.	

1.1.5

The bulkheads in the cargo hold region are to be spaced at uniform intervals as far as practicable.

2 *COLLISION BULKHEAD*

2.1 Extent and position of collision bulkhead

2.1.1

A collision bulkhead is to be fitted on all ships and is to extend to the freeboard deck. It is to be located between 0.05 L_{LL} or 10 m, whichever is less, and except as may be permitted by the Administration, 0.08 L_{LL} or 0.05 L_{LL}+3 m, whichever is the greater, aft of the reference point, where the reference point is as defined in [2.1.2].

2.1.2

For ships without bulbous bows the reference point is to be taken where the forward end of L_{LL} coincides with the forward side of stem, on the waterline which L_{LL} is measured. For ships with bulbous bows, it is to be measured from the forward end of L_{LL} a distance x forward; where x is to be taken as the lesser of the following:

a) Half the distance, from FP_{LL} to the extreme forward end of the bulb extension.
b) 0.015 L_{LL}.
c) 3.0 m.

2.2 Arrangement of collision bulkhead

2.2.1

In general, the collision bulkhead is to be in one plane; however, the bulkhead may have steps or recesses provided that they are within the limits prescribed in [2.1.1] and [2.1.2].

2.2.2
Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. Reference is made to Ch1, Sec 2, [2.1].

3 AFT PEAK BULKHEAD

3.1 General

3.1.1
An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, alternative arrangements are specially considered.

ISC 3.1.1a Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules and effective means are to be provided to ensure the watertightness of the stern tube.

3.1.2
The aft peak bulkhead may be stepped below the freeboard deck, provided that the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.3
The aft peak bulkhead location on ships powered and/or controlled by equipment that do not require the fitting of a stern tube and/or rudder trunk are also subject to special consideration.

ISC 3.1.3a The location of the aft peak bulkhead on ships powered and/or controlled by equipment that does not require the fitting of a stern tube and/or rudder trunk is to be in accordance with paragraph 2.2.5, Section2, Chapter2, PART ONE of the Rules and if the relevant requirements of paragraph 1.1 of this Section are complied with, may be specially considered.

3.1.4
Provided that the aft peak bulkhead extends above the deepest load line, termination of the afterpeak bulkhead on a watertight deck lower than the freeboard deck can be accepted. In order to provide such a watertight deck a tight sealing of the rudder stock shall be fitted I n way of this deck or above.

Section 3 COMPARTMENT ARRANGEMENT

1 COFFERDAMS

1.1 Definition

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be kept gas-tight and is to be properly ventilated, provided with drainage arrangement, and of sufficient size to allow proper inspection, maintenance and safe evacuation.

1.2 *Arrangement of cofferdams 1.2.1*

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (including fuel oil, lubricating oil) and those intended for fresh water (water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

1.2.2

Furthermore, tanks carrying fresh water for human consumption are to be separated from other tanks containing substances hazardous to human health by cofferdams or other means as approved by the Society.

Note 1: Normally, tanks for fresh water and water ballast are considered non-hazardous.

1.2.3

Where a corner to corner situation occurs, tanks are not considered to be adjacent.

1.2.4

The cofferdams specified in [1.2.1] may be waived when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch6, Sec4, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases,
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves,
- the structural test is carried out with a test pressure increased by 1 m with respect to Ch1, Sec2, [3.8.4].

2 DOUBLE BOTTOM

2.1 General

2.1.1

A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size provided the safety of the ship is not impaired in the event of bottom or side damage as regulated in SOLAS II-1, Reg 9.

ISC 2.1.1a For bulk carriers, a double bottom may not be fitted in way of watertight tanks (including dry tanks) of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

2.2 *Extent of double bottom 2.2.1*

For bulk carriers, a double bottom is to be fitted extending from the collision bulkhead to the aft peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

For oil tankers, a double bottom is to be fitted to protect the cargo hold region and pump rooms. However the double bottom below pump rooms may be omitted provided that it is in compliance

with MARPOL, Annex I, Ch 4, Reg 22.

2.2.2
Where double bottom is required to be fitted, the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge in areas where hopper or double side spaces are not provided.

2.3 *Height of double bottom 2.3.1*
Unless otherwise specified, the height of the double bottom is not to be less than the lesser of:

- For oil tankers: *B*/15 or 2 m, however not less than 1.0 m measured at right angles to the shell plating at any cross section.
- For bulk carriers: *B*/20 or 2 m, however not less than 0.76 m measured vertically from the plane parallel with keel line to inner bottom.

2.4 *Small wells in double bottom tank 2.4.1*
Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom that complies with [2.1].

ISC 2.4.1a Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., are not to extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g., for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with requirements. In no case is the vertical distance from the bottom of such a well to a plane coinciding with the keel line to be less than 500 mm.

3 DOUBLE SIDE
3.1 Double side width
3.1.1 Oil tankers
The minimum double side width, W_{ds}, in m, is to be taken as the lesser of:

$$W_{ds} = 0.5 + \frac{DWT}{20000} \text{ but less not than } 1.0$$

$$W_{ds} = 2.0$$

3.1.2 *Bulk carriers*
Double side skin means a configuration where each ship side is constructed by the side shell and a longitudinal bulkhead connecting the double bottom and the deck. Hopper side tanks and topside tanks may, where fitted, be integral parts of the double side skin configuration.
The minimum double side width, W_{ds}, is not to be less than 1 m measured perpendicular to the side shell.

3.2 *Minimum clearance inside the double side*
3.2.1 Definition
The minimum clearance is defined as the shortest distance measured between assumed lines connecting the inner surfaces of the stiffeners on the inner and outer hulls.

3.2.2 *Minimum clearance dimensions*
The minimum clearance between the inner surfaces of the stiffeners inside the double side is not to be less than:

- 600 mm when the inner and/or the outer hulls are transversely framed,
- 800 mm when the inner and the outer hulls are longitudinally framed.

Outside the parallel part of the cargo hold, the clearance may be reduced but is not to be less than 600 mm.

4 *BALLAST TANKS*

4.1 Capacity and disposition of ballast tanks

4.1.1

All ships are to have ballast tanks of sufficient capacity that the ship may operate safely on ballast voyage. The capacity of ballast is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus ballast only, the ship's draught and trim can meet the requirements defined in:

- For oil tankers, Ch4, Sec 8, [3.1].
- In addition, for oil tankers, the moulded draught amidships, T_{mid}, excluding any hogging or sagging correction, is not to be less than:
  $T_{mid} = 2.0 + 0.02L_{LL}$, in m
- For bulk carriers, Ch4, Sec8, [4.1].

Section 4 ACCESS AND ESCAPE ARRANGEMENT

1 ENCLOSED SPACES

1.1 General

1.1.1 Special considerations

Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.

Where spaces have special considerations or requirements for access; e.g. security restrictions for the CO2 room to prevent unintentional release, these are to be considered in conjunction with the requirements of this section, and any conflicts should be raised as soon as possible for consideration by the Society.

ISC 1.1.1a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

1.1.2 *Enclosed spaces*

All enclosed spaces are to be accessible with appropriate access arrangements for easy inspection, survey and maintenance i.e. access is to allow unobstructed passage to items for inspection for personnel wearing the appropriate clothing, including personal protective equipment, and using all necessary tools and test equipment.

Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships' crew in accordance with industry standards accepted by the Society, notwithstanding the requirements set out in SOLAS or other relevant regulatory instruments.

ISC 1.1.2a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

1.1.3 *Spaces not explicitly covered by SOLAS*

For spaces which are not explicitly covered by SOLAS, ChII-1, Reg 3-6, the builder is to provide appropriate accesses arrangements for easy inspection, survey and maintenance in accordance with industry standards accepted by the Society. See also [1.1.5].

Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships' crew in accordance with industry standards accepted by the Society. Special measures for inspection and maintenance are to be put in place for small closed spaces for which the design causes impracticality for the access.

ISC 1.1.3a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

1.1.4 *Ventilation of normally unmanned spaces*

Unless otherwise specifically detailed in these Rules, normally unmanned spaces are to be capable of being ventilated through natural or forced ventilation. Such ventilation could be achieved through the inclusion of mushroom ventilators, gooseneck ventilators, ventilators with weather proof covers etc. Exchange air may be provided through permanent or temporary mechanical ventilation and air trunk systems or a suitable air exchange path through tank openings and ventilators.

1.1.5 *Permanent means of access to normally unmanned spaces*

Unless otherwise specifically detailed in these Rules, permanent means of access to normally unmanned spaces is to be provided in accordance with SOLAS, Ch II-1, Reg. 3-6.

For enclosed spaces, which are not explicitly covered by SOLAS, Ch II-1, Reg. 3-6, the requirements of the Convention and associated Resolutions should be applied as far as practicable. The size of openings providing access to or emergency egress from spaces not entered during operation, entered for maintenance or entered for regular inspections shall, in general, not be less than 600mm x 400mm if oval or in accordance with industry standards accepted by the Society if

circular.

ISC 1.1.5a The applicable requirements given in ISC Guidelines on Application of Marine Ergonomics may be applied.

2 CARGO AREA AND FORWARD SPACES

2.1 General

2.1.1 Means of access

Each space is to be provided with means of access as regulated in SOLAS, ChII-1, Reg 3-6. This requirement applies to:

- Oil tankers.
- Bulk carriers having a length of 150 m or above, irrespective of their gross tonnage.

2.1.2

All tanks are to be accessible for easy inspection.

Chapter 3 STRUCTURAL DESIGN PRINCIPLES

Section 1 MATERIAL

1 GENERAL

1.1 Standard of material 1.1.1

Materials used during construction are to comply with the Rules for Materials of the Society.

ISC 1.1.1a Materials used for hull structures are to comply with the relevant provisions of PART ONE of ISC Rules for Materials and Welding.

1.1.2

Other materials than those covered under [1.1.1] may be accepted, provided their specification (e.g. manufacture, chemical composition, mechanical properties, welding) is submitted to the Society for approval.

1.2 *Testing of materials 1.2.1*

Materials are to be tested in compliance with the applicable requirements of Rules for Materials of the Society.

ISC 1.2.1a Materials are to be tested in compliance with the applicable requirements of Chapter 1, PART ONE of ISC Rules for Materials and Welding.

1.3 *Manufacturing process*

1.3.1

The requirements of this section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice defined in the Rules and/or documents of the individual Society which incorporate IACS UR W and the applicable requirements of Rules for Materials of the Society.

In particular:

- Parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended.
- Specific preheating may be required before welding.
- Welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

ISC 1.3.1a Welding and other cold or hot manufacturing processes of this Section are to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of ISC Rules for Materials and Welding.

2 HULL STRUCTURAL STEEL

2.1 General

2.1.1 Young's modulus and Poisson's ratio

The Young's modulus for Carbon steel materials is equal to 206,000 N/mm^2 and the Poisson's ratio equal to 0.3.

2.1.2 *Steel material grades and mechanical properties*

Steel having a specified minimum yield stress of 235N/mm^2 is regarded as normal strength hull structural steel and is denoted by 'MS' for mild steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel and is denoted 'HT' for high tensile steel.

Material grades of hull structural steels are referred to as follows:

a) A, B, D and E denote normal strength steel grades.
b) AH, DH and EH denote higher strength steel grades.

Table1 gives the mechanical characteristics of steels generally used in the construction of ships.

2.1.3

Higher strength steels other than those indicated in Table 1 are considered by the Society on a case-by-case basis.

ISC 2.1.3a For higher tensile steels other than those indicated in Table 1, the chemical composition, deoxidation method, condition of supply and mechanical properties of the steels are to be submitted to ISC for approval.

Mechanical properties of hull steels *Table1*

Steel grades for plates with t_{as_built} 100 mm	R_{eH}, specified minimum yield stress, in N/mm^2	R_m, specified tensile strength, in N/mm^2
A-B-D-E	235	400 - 520
AH32-DH32-EH32-FH32	315	440 - 570
AH36-DH36-EH36-FH36	355	490 - 630
AH40-DH40-EH40-FH40	390	510 - 660

2.1.4 High tensile steel

When steels with a specified minimum yield stress R_{eH} other than 235 N/mm^2 are used, hull girder strength and hull scantlings are to be determined by taking into account the material factor, k defined in [2.2].

2.1.5 *Onboard documents*

It is required to keep onboard a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Table 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available onboard together with the above plan.

2.2 *Material factor, k*

2.2.1

Unless otherwise specified, the material factor, k of normal and higher strength steel for hull girder strength and scantling purposes is to be taken as defined in Table 2, as a function of the specified minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k is obtained by linear interpolation.

Steels with a specified minimum yield stress R_{eH}, greater than 390 N/mm^2 are considered by the Society on a case-by-case basis.

Material factor, *k* **Table2**

R_{eH}, specified minimum yield stress, in N/mm^2	k
235	1.00
315	0.78
355	0.72
390	0.68

2.3 *Steel grades*

2.3.1

Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 3 to Table 7. General requirements are given in Table 3, while additional minimum requirements for ships with length exceeding 150m and 250m, single side bulk carriers with length exceeding 150 m, are given in Table 4 to Table 6. The

material grade requirements for hull members of each class depending on the thickness are defined in Table 7.

Material classes and grades *Table3*

	Structural member category	Material class/grade
Secondary	A1. Longitudinal bulkhead strakes, other than those belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	- Class I within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Primary	B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in topside tank	- Class II within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Special	C1. Sheer strake at strength deck (1) C2. Stringer plate in strength deck (1) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C4. Strength deck plating at outboard corners of cargo hatch openings for ships with hatch opening configurations similar to those of container carriers	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Min. Class III within cargo hold region
	C5. Strength deck plating at corners of cargo hatch openings	- Class III within 0.6 *L* amidships - Class II within rest of cargo hold region
	C6. Bilge strake of ships with double bottom over the full breadth and with length less than 150 m	- Class II within 0.6 *L* amidships - Class I outside 0.6 *L* amidships
	C7. Bilge strake in other ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C8. Longitudinal hatch coamings of length greater than 0.15 *L* including coaming top plate and flange C9. End brackets and deckhouse transition of longitudinal cargo hatch coamings	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Not to be less than Grade D/DH

(1) Single strakes required to be of class III within 0.4*L* amidships are to have breadths not less than 800+5*L*, in mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.

Minimum material grades for ships with length exceeding 150 m **Table4**

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength	Grade B/AH within 0.4 *L* amidships
Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0.4 *L* amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo hold region

Minimum material grades for ships with length exceeding 250 m Table 5

Structural member category(1)	Material grade
Sheer strake at strength deck	Grade E/EH within 0.4 *L* amidships
Stringer plate in strength deck	Grade E/EH within 0.4 *L* amidships
Bilge strake	Grade D/DH within 0.4 *L* amidships

(1) Single strakes required to be of Grade D/DH or Grade E/EH as shown in the above table and within 0.4*L* amidships are to have breadths not less than 800+5*L* (mm), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.

Minimum material grades for single side skin bulk carriers with length exceeding 150 m Table 6

Structural member category	Material grade
Lower bracket of ordinary side frame (1), (2)	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125 above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (2)	Grade D/DH

(1) The term 'lower bracket' means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125 above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.

(2) The span of the side frame, *l*, is defined as the distance between the supporting structures (see Pt 2, Ch1, Sec 2, Figure 2).

Material grade requirements for classes I, II and III Table7

Class	I		II		III	
As-built thickness, in mm	MS	HT	MS	HT	MS	HT
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

2.3.2

For strength members not mentioned in Table 3 to Table 6, Grade A/AH may be used upon agreement of the Society.

ISC 2.3.2a For strength members not mentioned in Table 3 to Table 6, Grade A/AH is generally to be used.

2.3.3

Plating materials for stern frames and shaft brackets are in general not to be of lower grades than corresponding to Class II.

2.4 Structures exposed to low air temperature

2.4.1

For ships intended to operate in areas with low air temperatures refer to Ch1, Sec 2, [3.4.4].

ISC 2.4.1a For ships intended to operate in areas with low air temperatures (with design temperature below and including -10 ºC),e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D of ISC 2.4.1e and in accordance with the provisions of ISC 2.4.1b to ISC 2.4.1e.

ISC 2.4.1b Grades of hull structural steel above the lowest ballast waterline (BWL) exposed to low air temperatures are not to be lower than those as given in Table ISC 2.4.1b.

ISC 2.4.1c Grades of steel for hull structural members of different material classes are to be selected according to Table ISC 2.4.1cdepending on plate thickness and design temperature. Where the design temperature t_D is below -55ºC, the grades of steel are to be subject to special consideration by ISC.

ISC 2.4.1d Single *strakes required to be of Class III or of grade E/EH or FH are to have breadths not less than 800+5L mm (L being length of the ship), but need not be greater than 1,800 mm.*

Material Classes at Low Air Temperatures ***Table ISC 2.4.1b***

Structural member category	*Structural member*	*Material class*	
		Within 0.4L amidships	*Outside 0.4L amidships*
Secondary	*Deck plating exposed to weather in general, side plating above BWL, transverse bulkheads above BWL*	*I*	*I*
Primary	*Strength deck plating*① *Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings* *Longitudinal bulkhead above BWL* *Top wing tank bulkhead above BWL*	*II*	*I*
Special	*Sheer strake at strength deck, including rounded gunwale*② *Stringer plate in strength deck*② *Deck strake at longitudinal bulkhead*③ *Continuous longitudinal hatch coamings*④	*III*	*II*

*Notes:*① *Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.*

② *Not to be less than grade E/EH within 0.4 L amidships in ships with length exceeding 250 m.*

③ *In ships with breadth exceeding 70 m at least three deck strakes to be Class III.*

④ *Not to be less than grade D/DH.*

Material Grade Requirements for Classes I, II and III at Low Temperatures

Table ISC 2.4.1c

Class I										
Plate thickness (mm)	*–11 ~ –15℃*		*–16 ~ –25℃*		*–26 ~ –35℃*		*–36 ~ –45℃*		*–46 ~ –55℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*A*	*AH*	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*
10<t≤15	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*
15<t≤20	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
20<t≤25	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
25<t≤30	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
30<t≤35	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*

Class I										
Plate thickness (mm)	*–11 ~ –15℃*		*–16 ~ –25℃*		*–26 ~ –35℃*		*–36 ~ –45℃*		*–46 ~ –55℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
35<t≤45	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*
45<t≤50	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*
Class II										
Plate thickness (mm)	*–11 ~ –15℃*		*–16 ~ –25℃*		*–26 ~ –35℃*		*–36 ~ –45℃*		*–46 ~ –55℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
10<t≤20	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
20<t≤30	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*
30<t≤40	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*
40<t≤45	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*	–	–
45<t≤50	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*	–	–
Class III										
Plate thickness (mm)	*–11 ~ –15℃*		*–16 ~ –25℃*		*–26 ~ –35℃*		*–36 ~ –45℃*		*–46 ~ –55℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
10<t≤20	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*
20<t≤25	*D*	*DH*	*E*	*EH*	*E*	*EH*	*E*	*FH*	–	*FH*
25<t≤30	*D*	*DH*	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*
30<t≤35	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*	–	–
35<t≤40	*E*	*EH*	*E*	*EH*	–	*FH*	–	*FH*	–	–
40<t≤50	*E*	*EH*	–	*FH*	–	*FH*	–	–	–	–

Note: "–" in the Table = Not applicable.

ISC 2.4.1e The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

mean: statistical mean over observation period (at least 20 years)

average: average during one day and night

lowest: lowest during year

For seasonally restricted service the lowest value within the period of operation applies. Figure

ISC 2.4.1e illustrates the temperature definition.

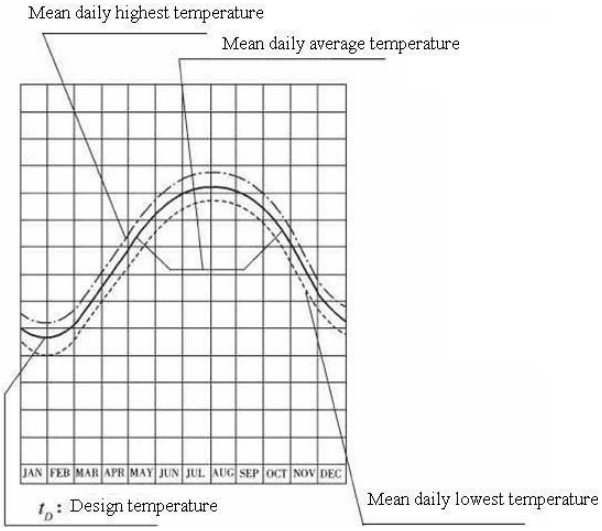


Figure ISC 2.4.1e Commonly Used Definitions of Temperatures

2.4 *Through thickness property 2.5.1*

Where tee or cruciform connections employ partial or full penetration welds, and the plate material is subject to significant tensile strain in a direction perpendicular to the rolled surfaces, consideration is to be given to the use of special material with specified through thickness properties, in accordance with the Rules for Materials of the Society. These steels are to be designated on the approved plan by the required steel strength grade followed by the letter Z (e.g. EH36Z).

ISC 2.5.1a Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant stress in through-thickness direction, Z-direction steels with full thickness properties are to be used, which are to comply with the requirements of Section 10, Chapter 3, PART ONE of ISC Rules for Materials and Welding.

2.5 *Stainless steel*

2.6.1

The reduction of strength of stainless steel with increasing temperature is to be taken into account in the calculation of the material factor, *k* and in the material Young's modulus, *E*.

Stainless steels are considered by the Society on a case-by-case basis.

ISC 2.6.1a The material Young's modulus, E, the material factor, k, and minimum yield stress, R_{eH}, are to comply with the requirements respectively, for elastic modulus specified in [1.3.6.2] and for material factor K and minimum yield strength Re_{HT} specified in [1.3.6.3], Section 3, Chapter 1, Part 2 of ISC Rules for Classification of Sea-Going Steel Ships.

3 STEELS FOR FORGING AND CASTING

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Rules for Materials of the Society.

ISC 3.1.1a Mechanical properties and chemical composition of steel forgings and castings to be used for structural members are to comply with the requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of ISC Rules for Materials and Welding.

3.1.2
Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

ISC 3.1.2a Steels of structural members intended to be welded are to comply with the applicable requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of ISC Rules for Materials and Welding.

3.1.3
The steels used are to be tested in accordance with the applicable requirements of the Rules for Materials of the Society.
ISC 3.1.3a The steel forgings and castings used are to be tested in accordance with the applicable requirements of 5.1.5, Section 1, Chapter 5 and 6.1.6, Section 1, Chapter 6 of PART ONE of ISC Rules for Materials and Welding.

3.2 Steels for forging
3.2.1
Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis. In such case, compliance with the applicable requirements of the Rules for Materials of the Society, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

ISC 3.2.1a Rolled bars in general may not be accepted in lieu of steel forgings for primary hull structures (e.g. rudder stock). Where they are used for those other than primary structural members, they are to be subject to the agreement of ISC. In this case, the quality and testing are to comply with relevant requirements for forgings in Chapter 5, PART ONE of ISC Rules for Materials and Welding.

3.3 Steels for casting
3.3.1
Cast parts intended for stems and stern frames in general may be made of C and C-Mn weldable steels, having specified minimum tensile strength, R_m=400N/mm^2, in accordance with the applicable requirements of the Society's Rules for Materials.

ISC 3.3.1a Steel castings intended for stems, stern frames, rudders, parts of steering gear and deck machinery are to comply with the requirements for carbon and carbon-manganese weldable steels having minimum tensile strength, R_m= 400 N/mm^2, specified in Section 2, Chapter 6, PART ONE of ISC Rules for Materials and Welding.

3.3.2
The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

ISC 3.3.2a For the welding of steel castings to main plating contributing to hull strength members, the technological measures such as preheating temperature and post-weld heat treatment are to be determined in accordance with the carbon equivalent and structural rigidness, subject to the agreement of ISC.
The impact properties and non-destructive examinations of steel castings for primary hull structures are to comply with the respective requirements of 6.2.4.3, Section 2 and 6.1.8, Section 1, Chapter 6, PART ONE of ISC Rules for Materials and Welding.

4 ALUMINIUM ALLOYS

4.1 General

4.1.1

The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components is to be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

Material requirements and scantlings are to comply with the Rules for Materials of the Society. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

ISC 4.1.1a Aluminium alloys are to comply with the requirements of Chapter 8, PART ONE of ISC Rules for Materials and Welding.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

ISC 4.1.2a When the design temperature of aluminium alloy structures for low temperature service is lower than -55ºC, 5083 aluminium alloys in annealed condition are to be used.

4.1.3

Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70,000 N/mm^2 and the Poisson's ratio equal to 0.33.

4.1.4

Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

4.2 *Extruded plating*

4.2.1

Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2

In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case-by-case basis.

ISC 4.2.2a In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. For other uses, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2 of the Rules.

4.2.3

Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4

Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1

Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2

The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111. Higher mechanical characteristics may be considered, provided they are duly justified.

4.3.3

The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

ISC 4.3.3a The as-welded properties of aluminium alloys of series 6000 are to comply with the requirements of 3.2.6.1, Section 2, Chapter 3, PART THREE of ISC Rules for Materials and Welding.

4.3 *Material factor, k*

4.4.1

The material factor, k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{\text{lim}}}$$

where:

R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0.2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2.

$R'_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition.
$R'_{p0.2} = \eta_1 R_{p0.2}$

R'_m : Minimum guaranteed tensile strength, in N/mm^2, of material in welded condition.
$R'_m = \eta_2 R_m$

$R_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition.

R_m : Minimum guaranteed tensile strength, in N/mm^2, of the parent metal in delivery condition.

η_1, η_2 : Specified in Table 8.

Aluminium alloys - Coefficients for welded construction **Table 8**

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0.2}/R_{p0.2}$	R'_m/R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0.2}/R_{p0.2}$	0.6
(1) When no information is available, coefficient η_1, is to be taken equal to the metallurgical efficiency coefficient β as defined in Table 9.		

Aluminium alloys - Metallurgical efficiency coefficient **Table 9**

Aluminium alloy	Temper condition	As-built thickness, in mm	β
6005A(Open sections)	T5 or T6	$t \leq 6$	0.45
		$t > 6$	0.40
6005A(Closed sections)	T5 or T6	All	0.50
6061 (Sections)	T6	All	0.53
6082 (Sections)	T6	All	0.45

4.4.2

In the case of welding of two different aluminium alloys, the material factor, k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.4 *Others*

4.5.1

Aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided. Where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump rooms are to satisfy the requirements of Pt 2, Ch2, Sec 2, [1.2] for aluminium anodes.

4.5.2
The underside of heavy portable aluminium structures such as gangways, is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

5 OTHER MATERIALS AND PRODUCTS

5.1 General

5.1.1
Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of the Rules for Materials of the Society.

ISC 5.1.1a Other materials and products such as parts made of iron castings, products made of copper alloys, rivets, anchors, chain cables and wire ropes are in general to comply with the applicable requirements of Chapters 7 to 10 of PART ONE of ISC Rules for Materials and Welding.

ISC 5.1.1b The materials of cranes, masts, derrick posts, derricks and accessories are to be selected based on factors such as design temperatures, plate thickness and type of cranes in accordance with the requirements of Chapter 6 of ISC Rules for Lifting Appliances of Ships and Offshore Installations.

5.1.2
The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

ISC 5.1.2a Plastics and other non-metallic materials are to comply with the requirements of PART TWO of ISC Rules for Materials and Welding.

5.2 Iron cast parts

5.2.1
As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2
Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

ISC 5.2.2a Iron castings are in general not be used for windows or sidescuttles. Iron castings not less than 300 N/mm^2 in specified minimum tensile strength and not less than 15% in specified minimum elongation may be used subject to the agreement of ISC.

Section 2 NET SCANTLING APPROACH

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4

t : Net thickness in mm.

t_c : Corrosion addition in mm.

t_{gr} : Gross thickness in mm.

h_{stf} : Height of stiffener or primary supporting member in mm.

h_w : Web height of stiffener or primary supporting member in mm.

t_w : Web thickness of stiffener or primary supporting member in mm.

b_f : Face plate width of stiffener or primary supporting member in mm.

t_f : Face plate thickness of stiffener or primary supporting member in mm.

t_p : Thickness of the plating attached to a stiffener or to a primary supporting member in mm.

d_f : Distance in mm, for the extension of flange for L2 profiles, see Figure 3.

t_{as_built} : As-built thickness, in mm, taken as the actual thickness provided at the newbuilding stage.

t_{gr_off} : Gross offered thickness, in mm, as defined in [1.2.2].

t_{gr_req} : Gross required thickness, in mm, as defined in [1.2.1].

t_{off} : Net offered thickness, in mm, as defined in [1.2.3].

t_{dm} : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

t_{req} : Net required thickness, in mm, as required in [1.3.1].

t_{vol_add} : Thickness for voluntary addition, in mm, taken as the thickness voluntarily added as the owner's extra margin or builder's extra margin for corrosion wastage in addition to t_c.

t_{res} : Reserve thickness, in mm, taken equal to 0.5 mm.

t_{c1}, t_{c2} : Corrosion addition on one side of the considered structural member, in mm, as defined in Ch3, Sec 3, Table 1.

1 GENERAL

1.1 Application

1.1.1 Net thickness approach

The net thickness, t, of a structural element is required for structural strength in compliance with the design basis. The corrosion addition, t_c, for a structural element is derived independently from the net scantling requirements as shown in Figure 1. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the ship-in-operation phase. This approach enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

1.1.2 *Local and global corrosion*

The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the average corrosion of larger areas, such as primary supporting members and the hull girder.

1.1.3 *Exceptions in gross scantling*

Items that are directly determined in terms of gross scantlings do not follow the net scantling approach, i.e. they already include additions for corrosion but without any owner's extra margin. Gross scantling requirements are identified with the suffix "gr" and examples are:

- Scantlings of superstructures and deckhouses as given in Ch11, Sec 1.
- Scantlings of massive pieces made of steel forgings and steel castings.

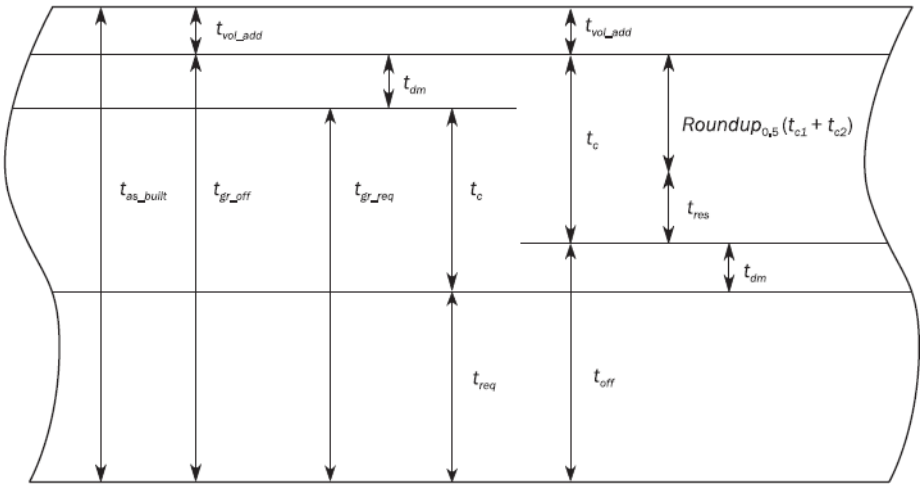


Figure1 Net scantling approach scheme

1.2 Gross and net scantling definitions

1.2.1 Gross required thickness

The gross required thickness, t_{gr_req}, is the thickness obtained by adding the corrosion addition as defined in Ch3, Sec 3 to the net required thickness, as follows:

$t_{gr_req} = t_{req} + t_c$

1.2.2 *Gross offered thickness*

The gross offered thickness, t_{gr_off}, is the gross thickness provided at the newbuilding stage, which is obtained by deducting any thickness for voluntary addition from the as-built thickness, as follows:

$t_{gr_off} = t_{as_built} - t_{vol_add}$

1.2.3 *Net offered thickness*

The net offered thickness, t_{off}, is obtained by subtracting the corrosion addition from the gross offered thickness, as follows:

$t_{off} = t_{gr_off} - t_c = t_{as_built} - t_{vol_add} - t_c$

1.3 *Scantling compliance*

1.3.1

The net required thickness, t_{req}, is obtained by rounding the net thickness calculated according to the Rules to the nearest half millimetre. For example:

1.3.1 For $10.75 \leq t < 11.25$ mm, the Rule required net thickness is 11.0 mm.

1.3.2 For $11.25 \leq t < 11.75$ mm, the Rule required net thickness is 11.5 mm.

1.3.2

Scantling compliance in relation to the Rules is as follow:

- The net offered thickness of plating is to be equal to or greater than the net required thickness of plating.
- The required net section modulus, moment of inertia and shear area properties of local supporting members are to be calculated using the net thickness of the attached plate, web and flange. The net sectional dimensions of local supporting members are defined in Figure 2. The required section modulus and web net thickness apply to areas clear of the end brackets.
- The offered net sectional properties of primary supporting members and the hull girder are to be equal to or greater than the required net sectional properties which are to be based on the gross offered scantling with a reduction of the applicable corrosion addition, as specified in Table 1, applied to all component structural members.
- The strength assessment methods prescribed are to be assessed by applying the corrosion reduction specified in Table 1 to the offered gross scantlings. Half of the applied corrosion addition specified in Table 1 is to be deducted from both sides of the

structural members being considered.

- Corrosion additions are not to be taken less than those given in Ch3, Sec 3, [1.2].

Any additional thickness specified by the owner or the builder is not to be included when considering the compliance with the Rules.

The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position are to be determined applying a corrosion magnitude of 0.5 t_c deducted from the surface of the profile cross- section.

Assessment for corrosion applied to the gross scantlings Table1

Structural requirement	Property/analysis type	Applied corrosion addition
Minimum thickness (all members including PSM)	Thickness	t_c
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties	t_c
	Stiffness / proportions /Buckling capacity	t_c
Primary supporting members (prescriptive)	Sectional properties	$0.5t_c$
	Stiffness/proportions of web and flange Buckling capacity	t_c
Strength assessment by FEM	Cargo tank/cargo hold	$0.5t_c$
	Buckling capacity	t_c
	Local fine mesh	$0.5t_c$
	Specified fine mesh areas	$0.5t_c$
Hull girder strength	Sectional properties	$0.5t_c$
	Buckling capacity	t_c
Hull girder ultimate strength Hull girder residual strength	Sectional properties	$0.5t_c$
	Buckling/collapse capacity	$0.5t_c$
Fatigue assessment (simplified stress analysis)	Hull girder section properties Local support member	$0.5t_c$
Fatigue assessment (FE Stress analysis)	Coarse mesh FE model Very fine mesh portion	$0.5t_c$

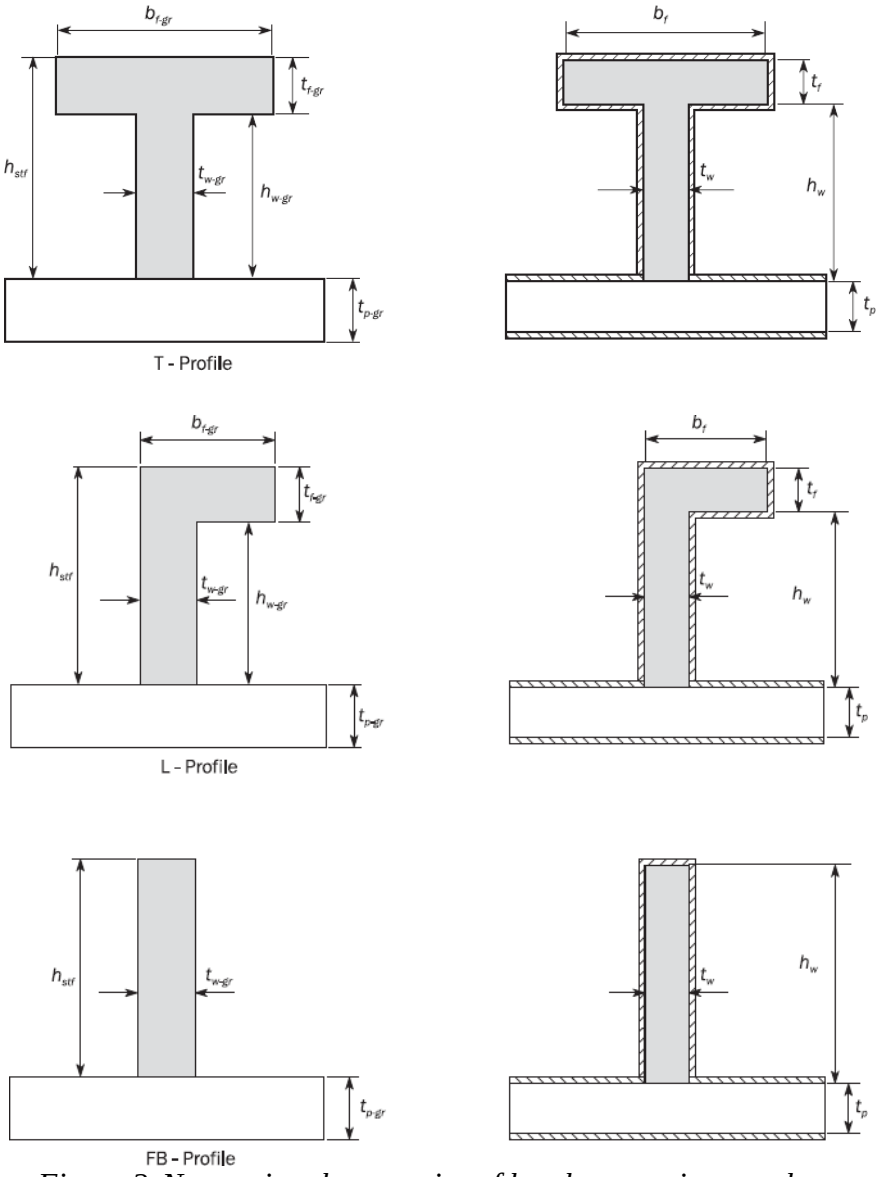


Figure 2 Net sectional properties of local supporting members

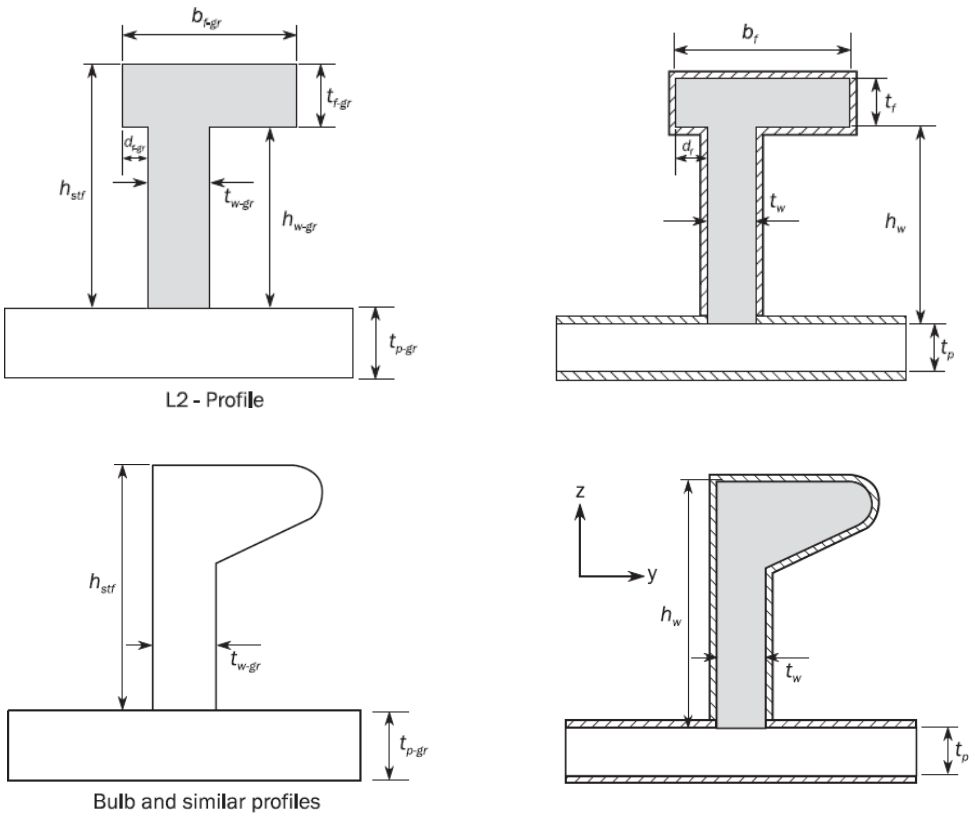


Figure 3 Net sectional properties of local supporting members (continued)

Section 3 CORROSION ADDITIONS

SYMBOLS

t_c : Corrosion addition, in mm.

t_{c1}, t_{c2} : Corrosion addition, in mm, on one side of the considered structural member, as defined in Table 1.

t_{res} : Reserve thickness, taken as 0.5 mm.

1 GENERAL

1.1 Applicability

1.1.1

The corrosion additions given in these Rules are applicable to carbon-manganese steels, stainless steels, stainless clad steels and aluminium alloys. Corrosion addition for the exposed carbon steel side of stainless clad structure is to be as required in Table 1 for the corresponding compartment.

The corrosion additions for other materials are to be in accordance with the requirements of the Society.

ISC 1.1.1a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of ISC.

1.2 *Corrosion addition determination 1.2.1*

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2}, is specified in Table 1.

The total corrosion addition, *tc*, in mm, for both sides of the structural member is obtained by the following formula:

$t_c = Roundup_{0.5}(t_{c1} + t_{c2}) + t_{res}$

For an internal member within a given compartment, the total corrosion addition, *tc* is obtained from the following formula:

$t_c = Roundup_{0.5} (2t_{c1}) + t_{res}$

where t_{c1} is the value specified in Table 1 for one side exposure to that compartment.

$Roundup_{0.5}$ (t) means that *t* is rounded to the upper half millimetre.

The total corrosion addition, t_c, in mm, for compartment boundaries and internal members made from stainless steel, or aluminium is to be taken as:

$t_c = t_{res} = 0.5$

In case of stainless clad steel, the corrosion additions, t_{c1}, for the carbon steel side and t_{c2}, for the stainless steel side are respectively to be taken as:

- t_{c1} as specified for the corresponding compartment in Table 1
- $t_{c2} = 0$

1.2.2 *Minimum value of total corrosion addition*

The total corrosion addition is not to be taken less than 2 mm except for web and face plate of stiffeners or in way of internals of dry spaces where 1.5 mm is applicable.

These minimum values of corrosion addition are not applicable to structural members made of stainless steels, stainless clad steels or aluminium alloys.

1.2.3 *Stiffener*

The corrosion addition of a stiffener is determined according to the location of its connection to the attached plating.

1.2.4
When a local structural member/plate is affected by more than one value of corrosion addition, the most onerous value is to be applied to the entire strake.

However, for the vertical corrugations arranged by vertical seams in oil tankers, the actual corrosion additions above and below the line 3m below top of tank (as defined in Table 1) can be used for the parts above and below the line, respectively.

Corrosion addition for one side of a structural member *Table1*

<table>
<tr><td rowspan="2">Compartment type</td><td colspan="2" rowspan="2">Structural member</td><td colspan="3">t_{c1} or t_{c2}</td></tr>
<tr><td>Oil tankers</td><td>BC-A or BC-B ships with L_{LL}≥150 m</td><td>Other BC ships</td></tr>
<tr><td rowspan="4">Ballast water tank, bilge tank, drain storage tank, chain locker (1)</td><td rowspan="2">Face plate of PSM</td><td>Within 3m below top of tank (4)</td><td colspan="3">2.0</td></tr>
<tr><td>Elsewhere</td><td colspan="3">1.5</td></tr>
<tr><td rowspan="2">Other members (2) (3)</td><td>Within 3m below top of tank (4)</td><td colspan="3">1.7</td></tr>
<tr><td>Elsewhere</td><td colspan="3">1.2</td></tr>
<tr><td rowspan="6">Cargo oil tank, slop tank</td><td rowspan="2">Face plate of PSM</td><td>Within 3m below top of tank (4)</td><td>1.7</td><td colspan="2" rowspan="5">N/A</td></tr>
<tr><td>Elsewhere</td><td>1.4</td></tr>
<tr><td colspan="2">Inner-bottom plating/bottom of tank</td><td>2.1</td></tr>
<tr><td rowspan="2">Other members</td><td>Within 3m below top of tank (4)</td><td>1.7</td></tr>
<tr><td>Elsewhere</td><td>1.0</td></tr>
<tr><td rowspan="8">Dry bulk cargo hold (5)</td><td rowspan="3">Transverse bulkhead</td><td>Upper part (6)</td><td rowspan="8">N/A</td><td>2.4</td><td>1.0</td></tr>
<tr><td>Lower stool: sloping plate, vertical plate and top plate (7)</td><td>5.2</td><td>2.6</td></tr>
<tr><td>Other parts</td><td>3.0</td><td>1.5</td></tr>
<tr><td colspan="2">Sloped plating of hopper tank, inner bottom plating</td><td>3.7</td><td>2.4</td></tr>
<tr><td rowspan="4">Other members</td><td>Upper part (6)</td><td rowspan="2">1.8</td><td rowspan="2">1.0</td></tr>
<tr><td>Webs and flanges of the upper end brackets of side frames of single side bulk carriers</td></tr>
<tr><td>Webs and flanges of lower brackets of side frames of single side bulk carriers</td><td>2.2</td><td>1.2</td></tr>
<tr><td>Other parts</td><td>2.0</td><td>1.2</td></tr>
<tr><td rowspan="2">Exposed to atmosphere</td><td colspan="2">Weather deck plating</td><td colspan="3">1.7</td></tr>
<tr><td colspan="2">Other members</td><td colspan="3">1.0</td></tr>
<tr><td rowspan="2">Exposed to seawater</td><td colspan="2">Shell plating between the minimum design ballast draught waterline and the scantling draught waterline</td><td colspan="3">1.5</td></tr>
<tr><td colspan="2">Shell plating elsewhere</td><td colspan="3">1.0</td></tr>
<tr><td colspan="2">Fuel and lube oil tank</td><td colspan="3">0.7</td></tr>
<tr><td colspan="2">Fresh water tank</td><td colspan="3">0.7</td></tr>
<tr><td>Void spaces (8)</td><td colspan="2">Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space not common with a dry bulk cargo hold or ballast cargo hold, etc.</td><td colspan="3">0.7</td></tr>
<tr><td>Dry spaces</td><td colspan="2">Internals of machinery spaces, pump room, store rooms, steering gear space, etc.</td><td colspan="3">0.5</td></tr>
</table>

Compartment type	Structural member	t_{c1} or t_{c2}		
		Oil tankers	BC-A or BC-B ships with $L_{LL} \geq 150$ m	Other BC ships

(1) 1.0 mm is to be added to the plate surface within 3m above the upper surface of the chain locker bottom.
(2) 0.5 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks/slop tanks. 0.3mm is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks or heated fuel/lube oil tanks/slop tanks. Heated oil tanks are defined as tanks/slop tanks arranged with any form of heating capability (the most common type is heating coils).
(3) 0.7 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated fuel oil or lube oil tanks.
(4) Only applicable to cargo tanks/slop tanks and ballast tanks with weather deck as the tank top. The 3 m distance is measured vertically from and parallel to the top of the tank.
(5) Dry bulk cargo hold includes holds intended for the carriage of dry bulk cargoes, which may carry water ballast.
(6) Upper part of the cargo holds correspond to an area above the connection between the topside and the inner hull or side shell.
If there is no topside, the upper part corresponds to the upper one third of the cargo hold height (where a plane bulkhead is fitted in way of a dry bulk cargo hold, the upper part of the bulkhead is defined in the same manner).
(7) If there is no lower stool fitted (i.e. engine room bulkhead or fore peak bulkhead) or if a plane bulkhead is fitted, then this corrosion addition should be applied up to a height level with the opposing bulkhead stool in that hold. In the case where a stool is not fitted on the opposing bulkhead, the vertical extent of this zone is to be from the inner bottom to a height level with the top of the adjacent hopper sloping plate, but need not be taken as more than 3 m.
(8) For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as for a water ballast tank.

Section 4 CORROSION PROTECTION

1 GENERAL

1.1 Structures to be protected

1.1.1 Dedicated seawater ballast tanks

All dedicated seawater ballast tanks are to have an efficient corrosion prevention system.

ISC 1.1.1a Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards are to comply with the requirements of IMO SOLAS Regulation II-1/3-2 and to be coated during construction in accordance with the Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (PSPC-WBT).

1.1.2 *Cargo oil tanks*

Cargo oil tanks are to be protected in compliance with the requirements specified in Pt 2, Ch2, Sec 2, [1].

ISC 1.1.2a Cargo oil tanks of crude oil tankers of 5,000 tons deadweight and above are to comply with the requirements of IMO SOLAS Regulation II-1/3-11 and to be coated during construction in accordance with the Performance standard for protective coatings for cargo oil tanks of crude oil tankers (PSPC-COT) or protected by alternative means of corrosion protection or utilization of corrosion resistance material to maintain required structural integrity for 25 years in accordance with the Performance standard for alternative means of corrosion protection for cargo oil tanks of crude oil tankers.

1.1.3 *Bulk carriers*

Void double side skin spaces and cargo holds of bulk carriers are to be protected in compliance with the requirements specified respectively in Pt 2, Ch1, Sec 2, [2.2] and Pt 2, Ch1, Sec 2, [2.3].

1.1.4 *Narrow spaces*

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

2 *SACRIFICIAL ANODES*

2.1 Attachment of anodes to the hull

2.1.1

All anodes are to be attached to the structure in such a way that they remain securely fastened both initially and during service even when it is wasted. The following methods are acceptable:

a) Steel core connected to the structure by continuous fillet welds.
b) Attachment to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

Anodes are to be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.1.3

Where cores or supports are welded to local support members or primary supporting members, they are to be kept clear of end supports, toes of brackets and similar stress raisers. Where they are welded to asymmetrical members, the welding is to be at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate, but well clear of the free edges. Generally, anodes are not to be fitted to a face plate of higher strength steel.

2.1.4 *Cargo oil tanks*

Cathodic protection systems, if fitted in cargo oil tanks, are to comply the requirements specified Pt 2, Ch2, Sec 2, [1].

Section 5 LIMIT STATES

1 GENERAL

1.1 Limit states

1.1.1 Definition

A limit state is defined as a state beyond which the structure no longer satisfies the requirements. The following categories of limit states are relevant for structures:

- Serviceability limit state (SLS), which corresponds to conditions beyond which specified requirements are no longer met.
- Ultimate limit state (ULS), which corresponds to the maximum load carrying-capacity or, in some cases, to the maximum applicable strain or deformation, under intact (undamaged) conditions.
- Fatigue limit state (FLS), which corresponds to degradation due to effect of time varying (cyclic) loading.
- Accidental limit state (ALS), which concerns the ability of the structure to resist accident situations.

1.1.2 *Serviceability limit state*

Serviceability limit state, which concerns the normal use, includes:

- Local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members or non-structural elements.
- Unacceptable deformations which affect the efficient use and appearance of structural or non- structural elements or the functioning of safety equipment.

In the context of serviceability limit state, the term ‘appearance’ is concerned with such criteria as high deflection and extensive cracking, rather than aesthetics.

1.1.3 *Ultimate limit state*

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- Attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations or instability (buckling).
- Excessive yielding, transforming the structure or part of it into a plastic mechanism.

1.1.4 *Fatigue limit state*

Fatigue limit states assess that the fatigue capacity of structural members due to cyclic loads is greater than the design fatigue life.

1.1.5 *Accidental limit state*

Accidental limit states are concerned with the ability of the structure to resist accident situations or abnormal events. Flooded conditions of any compartment without progression of the flooding to another compartment are considered. The limit states are concerned with the following in intact (undamaged) conditions with accidental or abnormal loads, or in damaged conditions with environmental loads the ship meets during a limited time frame:

- The safety of life.
- Environment.
- Property (ship and cargo).

Accidental limit state includes:

- Loss of structural strength without loss of containment.
- Loss of structural strength and loss of containment.

1.2 *Failure modes*

1.2.1

A number of possible failure modes may be relevant for the various parts of the ship structure. For each failure mode, one or more limit states may be relevant. The failure modes to be considered for the assessment of ship structural safety with relation to the limit states are shown in Table 1.

Failure modes in relation to the limit states to be considered *Table1*

Possible failure modes to be considered	Limit states(1)			
	SLS	ULS	FLS	ALS
Yielding	Y	Y	-	Y
Plastic collapse	-	Y	-	Y
Buckling	Y	Y	-	Y
Rupture	-	Y	-	Y
Fatigue cracking	-	-	Y	-
Brittle fracture (2)	-	-	-	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) Controlled by the material rule requirement of steel grade.

1.2.2 Yielding

The yielding failure mode is the mode in which plastic strain locally occurs in the structural members to be considered under combined in-plane and normal stresses. Local plastic strain is controlled in SLS, ULS and ALS by checking that the stresses caused in the structural members remains below a permissible value.

1.2.3 *Plastic collapse*

The plastic collapse failure mode usually appears in the local structural members under large lateral impact pressure. In this failure mode, permanent lateral deflection in the local structural members occurs, but does not influence the global strength. This mode is controlled in ULS and ALS by using conventional plastic design method.

1.2.4 *Buckling*

The buckling failure mode is the instability phenomena of structural members under compressive loads. When the stress in structural members just attains the elastic buckling stress, elastic (reversible) buckling occurs during the compressive load. This buckling failure mode is controlled in SLS. By further increasing the compressive load, stress redistribution occurs due to buckling of the weakest structural member and the stress in some structural members reaches the yield stress. This buckling failure mode with large elastic deflection is controlled in ULS or ALS. When compression is unloaded, no consequence of failure due to buckling is seen.

On the other hand, plastic (irreversible) buckling occurs when the stress in structural members exceeds the yield stress. As a result, the substantial permanent deflections due to plastic buckling appear. This irreversible buckling failure mode is controlled only in ULS or ALS for global hull girder strength.

1.2.5 *Rupture*

The rupture failure mode is the mode in which breaking occurs in the structural members to be considered under large tensile stress beyond the yield stress of the material. This failure mode is controlled in ULS or ALS, but the assessment of this failure mode is covered by controlling the yielding failure.

1.2.6 *Brittle fracture*

Brittle fracture is dependent upon the material, temperature and thickness. Therefore, this mode is controlled by the material rule requirement of steel grade.

1.2.7 *Fatigue cracking*

This failure mode is different from the failure modes mentioned above and is controlled in FLS.

2 CRITERIA

2.1 General

2.1.1

Criteria are prescribed in the Rules to check the relevant limit states for the various structural elements. The strength assessments included in the Rules are defined in terms of yield check, buckling check, ultimate strength check, and fatigue check as indicated in Table 2.

Structural assessment **Table2**

Structural Elements (1)		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Stiffeners	Y	Y	Y(2)	Y
	Plating	Y	Y	Y(3)	-
Primary supporting members		Y	Y	Y(2)	Y
Hull girder		Y	Y(4)	Y	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) The ultimate strength check is included in the buckling check.
(3) The ultimate strength check of plating is included in the yielding check formula of plating.
(4) The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

2.2 Serviceability limit states

2.2.1 Hull girder

For the yielding check of the hull girder, the stress corresponds to a load at 10-8 probability level.

2.2.2 *Plating*

For the yielding check and buckling check of platings constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.

2.2.3 *Stiffeners*

For the yielding check of stiffeners, the stress corresponds to a load at 10-8 probability level.

2.3 *Ultimate limit states*

2.3.1 Hull girder

The ultimate strength of the hull girder is to be checked against the hull girder loads at 10^{-8} probability level, amplified with the partial safety factor.

2.3.2 *Plating*

The ultimate strength of the plating between stiffeners and primary supporting members is to be checked against the loads at 10^{-8} probability level.

2.3.3 *Stiffeners*

The ultimate strength of stiffeners is to be checked against the loads at 10^{-8} probability level.

2.4 *Fatigue limit state*

2.4.1 Structural details

The fatigue life of representative welded structural details such as connections of stiffeners and primary supporting members and free edge of bulk carrier deck plating in way of hatch corner is to be assessed from long term distribution loads based on loads at 10^{-2} probability level including the whipping-springing effects.

2.5 *Accidental limit state*

2.5.1 Hull girder

For bulk carriers, the yielding and ultimate strength of the hull girder in cargo hold flooded condition and in the damaged condition is to be assessed in accordance with Ch 5, Sec 1 and Ch 5, Sec 2.

The residual strength of oil tankers and bulk carriers is to be assessed according to Ch 5, Sec 3, for damages resulting from collision or grounding.

2.5.2 *Double bottom structure*

For bulk carriers, the double bottom structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3.

2.5.3 *Bulkhead structure*

For bulk carriers, the bulkhead structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3 and Pt 2, Ch 1, Sec 4.

2.5.4 *Plating, stiffeners and PSM*

The plating, stiffeners and PSM are to be assessed in flooded conditions in accordance with Ch 6 for yielding criteria and with Ch 8, Sec 3 for buckling criteria.

3 STRENGTH CHECK AGAINST IMPACT LOADS

3.1 General

3.1.1

Structural response against impact loads such as forward bottom slamming, bow impact and grab chocks depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillagei.e. platings between stiffeners and primary supporting members and stiffeners with attached platingis to be checked against the maximum impact loads acting on them.

Section 6 STRUCTURAL DETAIL PRINCIPLES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 APPLICATION

1.1 General

1.1.1

If not specified otherwise, the requirements of this section apply to the hull structure except superstructures and deckhouses.

2 GENERAL PRINCIPLES

2.1 Structural continuity

2.1.1 General

Attention is to be paid to the structural continuity, in particular in the following areas:

- In way of changes in the framing system.
- At end connections of primary supporting members or ordinary stiffeners.
- In way of the transition zones between cargo hold region and fore part, aft part and machinery space.
- In way of side and end bulkheads of superstructures.

At the termination of a structural member, structural continuity is to be maintained by the fitting of suitable supporting structure.

Abrupt changes in transverse section properties of longitudinal members are to be avoided. Smooth transitions are to be provided.

2.1.2 *Longitudinal members*

Longitudinal members are to be arranged in such a way that continuity of strength is maintained.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously as far as practicable towards the ends of the ship.

In particular, the structural continuity in way of longitudinal bulkheads within the cargo hold region, is to be maintained outside the cargo hold region. Large transition brackets (e.g. scarfing brackets) fitted in line with the longitudinal bulkhead are a possible means to achieve such structural continuity.

2.1.3 *Primary supporting members*

Primary supporting members are to be arranged in such a way that continuity of strength is maintained. Abrupt changes of web height or cross section are to be avoided.

2.1.4 *Stiffeners*

Stiffeners are to be arranged in such a way that continuity of strength is maintained.

Stiffeners contributing to the hull girder longitudinal strength are to be continuous when crossing primary supporting members within the 0.4L amidships and as far as practicable outside 0.4L amidships.

Where stiffeners are terminated in way of large openings, foundations and partial girders, compensation is to be arranged to provide structural continuity in way of the end connection.

2.1.5 *Plating*

Where plates with different thicknesses are joined, the change in the as-built plate thickness is not to exceed 50% of larger plate thickness in the load carrying direction. This also applies to the strengthening by local inserts, e.g. insert plates in double bottom girders, floors and inner bottom.

2.1.6 *Weld joints*

Weld joints are to be avoided in areas with high stress concentration.

2.2 *Local reinforcements*

2.2.1 Reinforcements at knuckles

a) Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle.

b) Whenever a knuckle in a main member (shell, longitudinal bulkhead etc) is arranged, stiffening in the form of webs, brackets or profiles is to be connected to the members to which they are to transfer the load (in shear). See example of reinforcement at upper hopper knuckle in Figure 1.

c) For longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

d) Generally, the distance between the knuckle and the support stiffening in line with the knuckle is not to be greater than 50 mm. Otherwise, fatigue analysis according to Ch 9 is to be submitted by the designer.

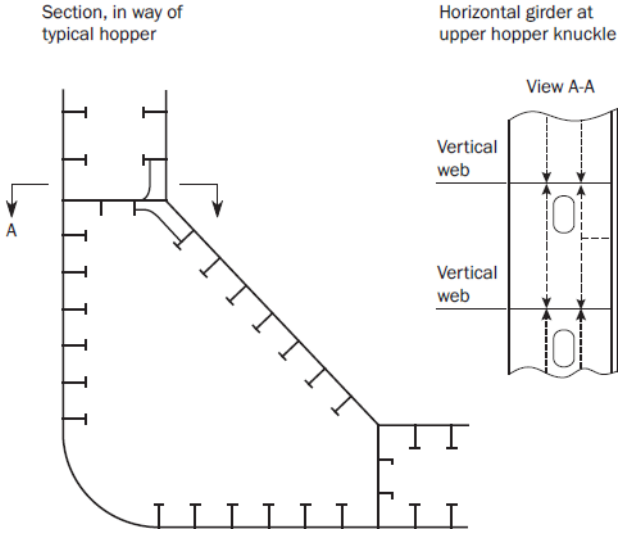


Figure 1 Example of reinforcement at knuckles

2.2.2 Reinforcement in way of attachments for permanent means of access

Local reinforcement, considering location and strength, is to be provided in way of attachments to the hull structure for permanent means of access.

2.2.3 *Reinforcement of deck structure in way of concentrated loads*

The deck structure is to be reinforced in way of concentrated loads, such as anchor windlass, deck machinery, cranes, masts and derrick posts.

2.2.4 *Reinforcement by insert plates*

Insert plates are to be made of materials with, at least, the same specified minimum yield stress and the same grade as the plates to which they are welded. See also [2.1.5].

2.3 *Connection of longitudinal members not contributing to the hull girder longitudinal strength*

2.3.1

Where the hull girder stress at the strength deck or at the bottom as defined in Ch 5, Sec 1, [2.2.2] is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel, longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge plating, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified

minimum yield stress as the strength deck or bottom structure steel.

2.3.2
The requirement in [2.3.1] is also applicable to non-continuous longitudinal stiffeners welded on the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress on those members is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel.

3 STIFFENERS

3.1 General

3.1.1
All types of stiffeners (excluding web stiffeners) are to be connected at their ends. However, in special cases such as isolated areas of the ship where end connections cannot be applied, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in [3.2] to [3.4].

3.1.2
Where the angle between the web plate of the stiffener and the attached plating is less than 50 deg as shown on Figure 2, a tripping bracket is to be fitted. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 deg, the face plate of the stiffener is to be fitted on the side of open angle.

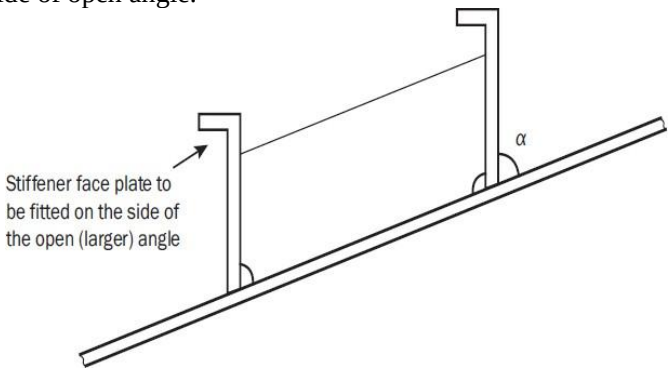


Figure 2 Stiffener on attached plating with an angle less than 50 deg

3.2 Bracketed end connections of non-continuous stiffeners

3.2.1
Where continuity of strength of longitudinal members is provided by brackets, the alignment of the brackets on each side of the primary supporting member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross sectional area are not less than those of the member.

3.2.2
At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member.

3.2.3
The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, is the section modulus to be less than that required for the stiffener.

3.2.4 *Net web thickness*
The net bracket web thickness, t_b, in mm, is to comply with the following:

$$t_b \geq (2 + f_{bkt}\sqrt{Z})\sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}} \text{ and need not be greater than 13.5 mm.}$$

where:
f_{bkt} : Coefficient taken as:

f_{bkt} = 0.2 for brackets with flange or edge stiffener.
f_{bkt} = 0.3 for brackets without flange or edge stiffener.

Z : Net required section modulus, of the stiffener, in cm*3*. In the case of two stiffeners connected, Z is the smallest net required section modulus of the two connected stiffeners.

$R_{eH\text{-}stf}$: Specified minimum yield stress of the stiffener material, in N/mm^2.

$R_{eH\text{-}bkt}$: Specified minimum yield stress of the bracket material, in N/mm^2.

3.2.5 *Brackets at the ends of non-continuous stiffeners*

Brackets are to be fitted at the ends of non-continuous stiffeners, with arm lengths, l_{bkt}, in mm, taken as:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z}{t_b}}$$

l_{bkt} is not to be taken less than:

- l_{bkt} = 1.8h_{stf} for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see item (c) in Figure 3.
- l_{bkt} = 2.0h_{stf} for other cases, see items (a), (b) and (d) in Figure 3.

where:

c_{bkt}: Coefficient taken as:

- c_{bkt} =65 for brackets with flange or edge stiffener.
- c_{bkt} =70 for brackets without flange or edge stiffener.

Z: Net required section modulus, for the stiffener, in cm*3*, as defined in [3.2.4].

t_b: Minimum net bracket thickness, in mm, as defined in [3.2.4].

For connections similar to item (b) in Figure 3, but not lapped, the bracket arm length is to comply with $l_{bkt} \geq 2.0h_{stf.}$

For connections similar to items (c) and (d) in Figure 3 where the smaller stiffener is connected to a primary supporting member or bulkhead, the bracket arm length is not to be less than two times of h_{stf}.

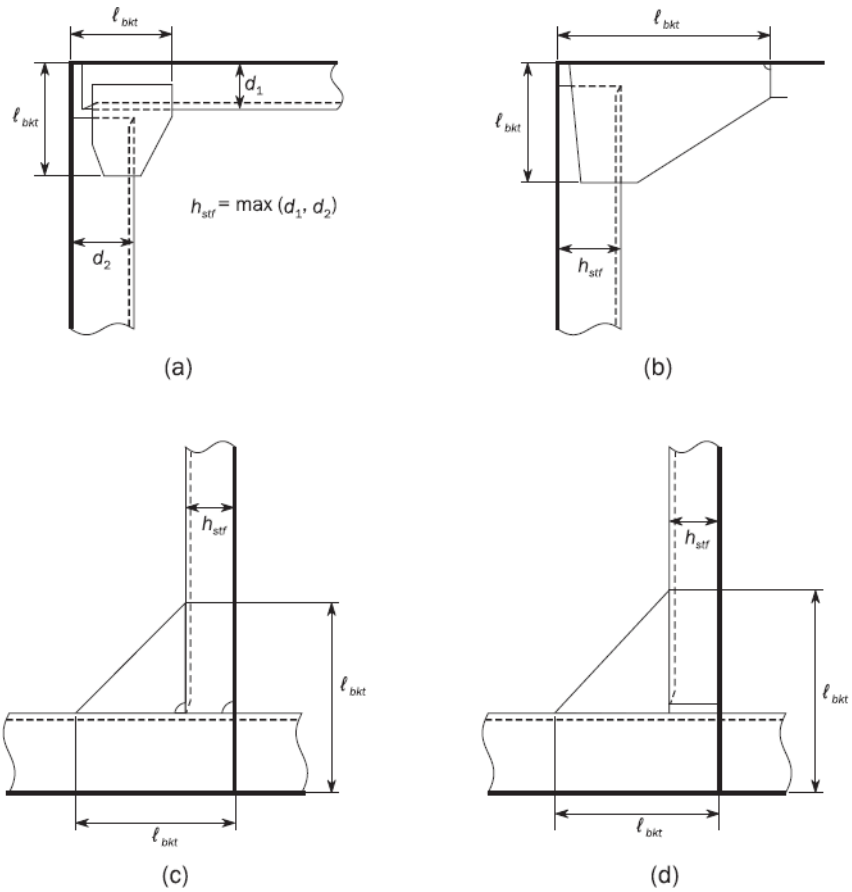


Figure 3 Bracket arm length of non-continuous stiffeners

3.2.6 Brackets with different arm lengths

The lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than $2l_{bkt}$ and each arm not to be less than 0.8 l_{bkt}, where l_{bkt} is as defined in [3.2.5].

3.2.7 *Edge stiffening of bracket*

Where an edge stiffener is required, the web height of the edge stiffener, h_w, in mm, is not to be less than:

$$h_w = 45\left(1+\frac{Z}{2000}\right) \quad \text{but not less than 50 mm.}$$

where:

Z : Net section modulus, of the stiffener, in cm^3, as defined in [3.2.4].

3.3 *Bracketless connections*

3.3.1

The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.4 *Sniped ends*

3.4.1

Sniped ends may be used where dynamic loads are small, provided the net thickness of plating supported by the stiffener, t_p, is not less than:

$$t_p = c_1\sqrt{\left(1000l-\frac{s}{2}\right)\frac{sPk}{10^6}}$$

where:

P : Design pressure for the stiffener for the design load set being considered, in kN/m^2.

c_1 : Coefficient for the design load set being considered, to be taken as:

c_1 = 1.2 for acceptance criteria set AC-S.
c_1 = 1.1 for acceptance criteria set AC-SD.

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators in the machinery space, propeller impulse zone in the stern area nor on the shell envelope.

3.4.2
Bracket toes and sniped stiffeners ends are to be terminated close to the adjacent member. The distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Tapering of the sniped end is not to be more than 30 deg, where it is not practical to comply with this requirement, alternative arrangements are specially considered. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

4 PRIMARY SUPPORTING MEMBERS (PSM)

4.1 General

4.1.1
Primary supporting members web stiffeners, tripping brackets and end brackets are to comply with [4.2] to [4.4]. Where the structural arrangement is such that these requirements cannot be complied with, adequate alternative arrangement has to be demonstrated by the designer.

4.2 *Web stiffening*

arrangement 4.2.1
Web stiffeners arranged on primary supporting members are to comply with the requirements to scantlings of such stiffeners are given in Ch 8, Sec 2, [4.2].

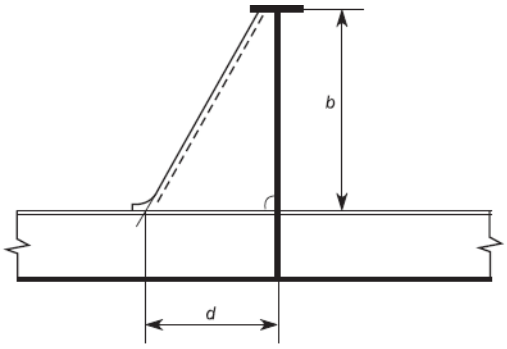
4.3 *Tripping bracket*

arrangement 4.3.1
Tripping brackets (see Figure 4) are generally to be fitted:

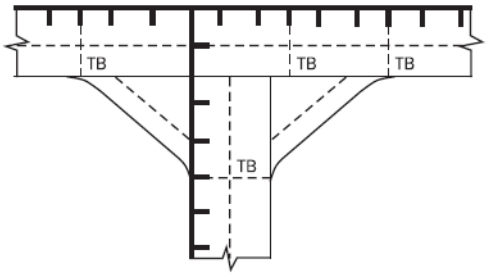
- At positions along the member span such that it satisfies the criteria of Ch 8, Sec 2, [5.1] for tripping bracket spacing and flange slenderness.
- At the toe of end brackets.
- At ends of continuous curved face plates.
- In way of concentrated loads.
- Near the change of section.

4.3.2
Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

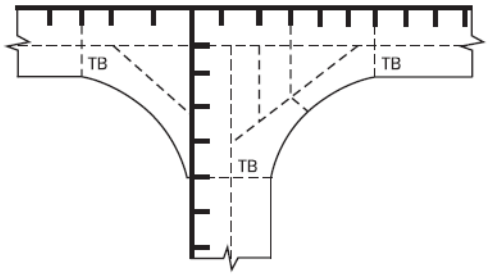
4.3.3
Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, a tripping bracket is to support the face plate.



Tripping bracket in way of stiffener



Tripping brackets at the toe of end brackets



Tripping brackets at the ends of continuous curved face plates

Figure 4 Primary supporting member: Tripping bracket arrangement

4.3.4 Arm length

The arm length of tripping brackets is not to be less than the greater of the following values, in m:

$d = 0.38\,b$

$$d = 0.85b\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Figure 4.

s_t : Spacing, in m, of tripping brackets.

t : Net thickness, in mm, of tripping brackets.

For tripping brackets in way of superstructures or deckhouses, only $d = 0.38\,b$ is to be applied.

4.4 *End connections*

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members. End brackets are generally to be soft-toed.

Bracketless connections may be applied provided that there is adequate support of adjoining face plates.

4.4.2 *Scantling of end brackets*

In general, the arm lengths of brackets connecting PSMs, as shown in Figure 5 are not to be less than the web depth of the member, and need not be taken greater than 1.5 times the web depth.

Within the cargo hold region the thickness of the bracket is, in general, not to be less than that of the adjoining PSM web plate. Outside of the cargo hold region the thickness of the bracket is not to be less than that of the PSM web plate.

Scantlings of the end brackets are to be such that the section modulus of the PSM with end bracket, excluding face plate where it is sniped, is not to be less than that of the primary supporting member at mid-span.

The net cross sectional area, A_f, in cm^2, of face plates of brackets is not to be less than:
$A_f = l_b\, t_b$
where:
l_b : Length of bracket edge, in m, see Figure 5. For brackets that are curved, the length of the bracket edge may be taken as the length of the tangent at the midpoint of the edge.
t_b: Minimum net bracket thickness, in mm, as defined in [3.2.4].

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

4.4.3 *Arrangement of end brackets*
Where the length of free edge of bracket, l_b, is greater than 1.5m, the web of the bracket is to be stiffened as follows:

- The net sectional area, in cm^2, of web stiffeners is to be not less than $16.5l$, where l is the span, in m, of the stiffener.
- Tripping flat bars are to be fitted. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

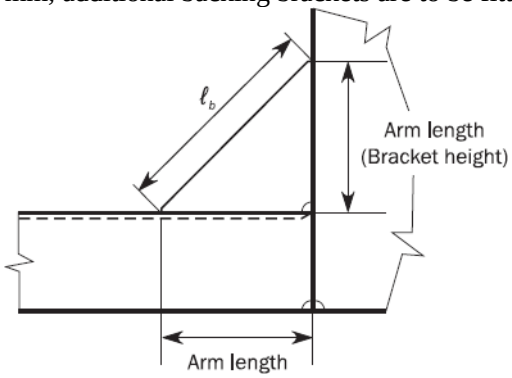


Figure 5 Dimension of brackets

For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The toes of brackets are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. In general, the end brackets of primary supporting members are to be soft-toed. Where primary supporting members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto the edge or welded adjacent to the edge of the end bracket (see Figure 6), the face plate is to be sniped and tapered at an angle not greater than 30°.

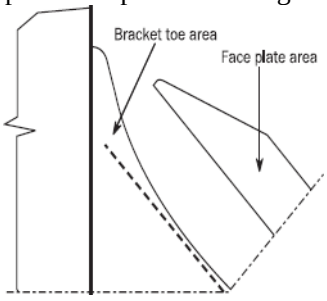


Figure 6 Bracket face plate adjacent to the edge

The details shown in this figure are only used to illustrate items described in the text and are not

intended to represent design guidance or recommendations.

5 INTERSECTION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

5.1 Cut-outs

5.1.1

Cut-outs for the passage of stiffeners through the web of primary supporting members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

5.1.2

The total depth of cut-outs without collar plate is to be not greater than 50% of the depth of the primary supporting member.

5.1.3

Cut-outs in way of cross tie ends and floors under bulkhead stools or in high stress areas are to be fitted with full collar plates, see Figure 7.

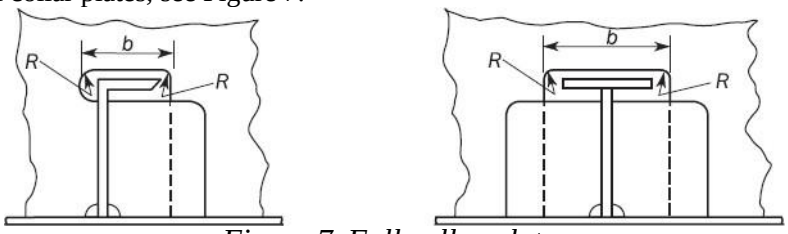
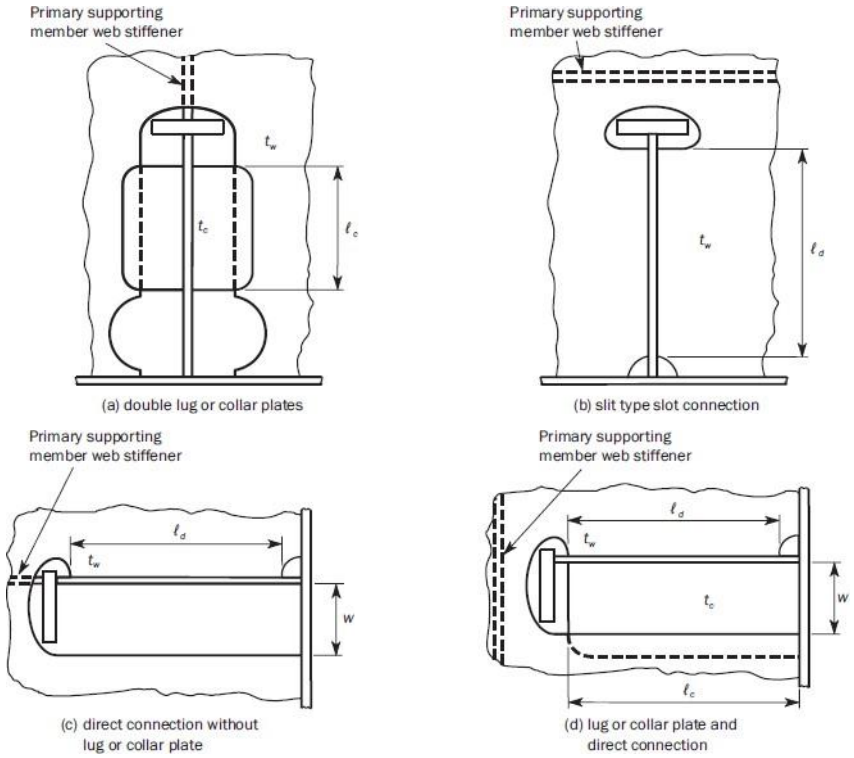


Figure 7 Full collar plates

$R \geq 0.2b$ but not less than 25 mm.



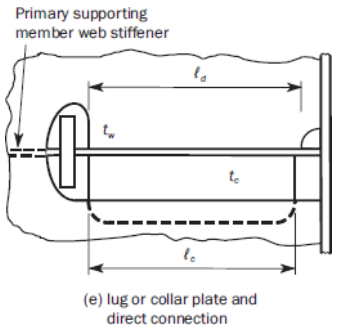
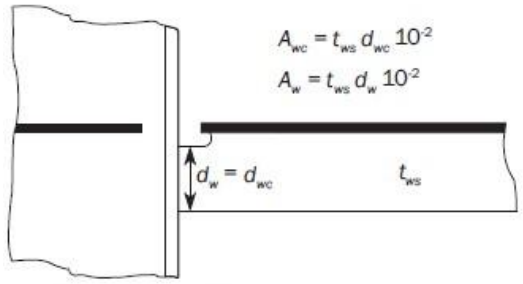
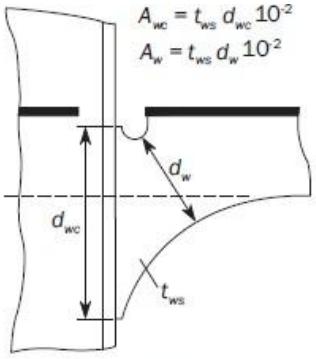


Figure 8 Symmetric and asymmetric cut-outs

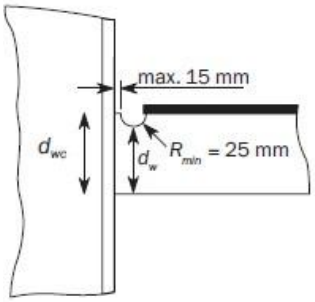
The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance.



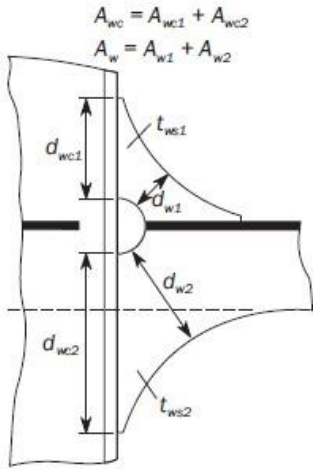
(a) Straight heel no bracket



(b) Soft toe and soft heel



(c) Keyhole in way of soft heel



(d) Symmetrical soft toe brackets

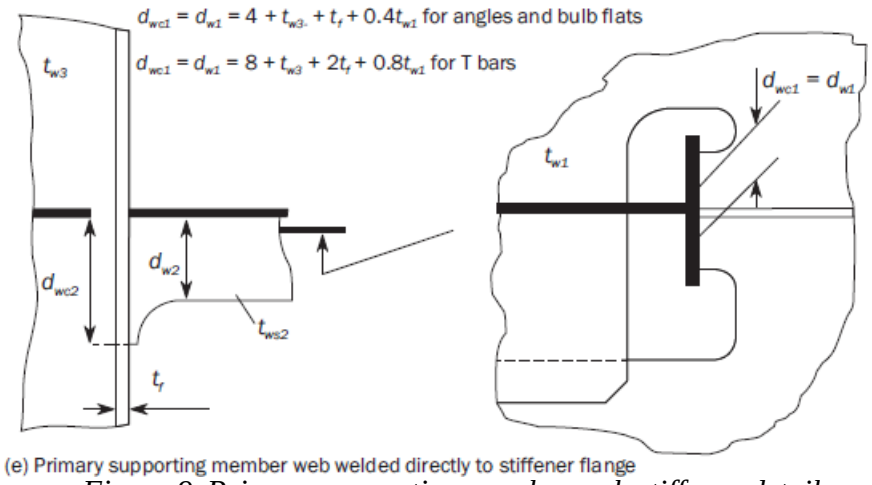


Figure 9 Primary supporting member web stiffener details

t_{ws}, t_{ws1}, t_{ws2} : Net thickness of the primary supporting member web stiffener/backing bracket, in mm.

d_w, d_{w1}, d_{w2} : Minimum depth of the primary supporting member web stiffener/backing bracket, in mm.

d_{wc}, d_{wc1}, d_{wc2}: Length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm.

t_f : Net thickness of the flange in mm. For bulb profile, t_f is to be obtained as defined in Pt.1 Ch.3 Sec.7 [1.4.1].

5.1.4

Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of [5.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Figure 8 for typical lug arrangements.

5.1.5

At connection to shell envelope longitudinals below the scantling draught, T_{sc} and at connection to inner bottom longitudinals, a soft heel is to be provided in way of the heel of the primary supporting member web stiffeners when the calculated direct stress, σ_w, in the primary supporting member web stiffener according to [5.2] exceeds 80% of the permissible values. The soft heel is to have a keyhole, similar to that shown in item (c) in Figure 9.

A soft heel is not required at the intersection with watertight bulkheads and primary supporting members, where a back bracket is fitted or where the primary supporting member web is welded to the stiffener face plate.

When calculating the direct stress, σ_w, the bottom slamming or bow impact loads using the design pressures defined in Ch 4, Sec 5, [3.2] and [3.3] need not be applied.

5.1.6

Cut-outs are to have rounded corners and the corner radii, R, are to be as large as practicable, with a minimum of 20% of the breadth, b, of the cut-out or 25 mm, whichever is greater. The corner radii, R, does not need to be greater than 50 mm, see Figure 7. Consideration is to be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

Note 1: Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

5.2 *Connection of stiffeners to PSM*

5.2.1 General

For connection of stiffeners to PSM in case of lateral pressure, [5.2.2] and [5.2.3] are to be applied.

The cross sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.2

The load, W_1, in kN, transmitted through the shear connection is to be taken as follows.

- If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_\alpha + \frac{A_1}{4 f_c A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:
  $W_1 = W$

where:

W: Total load, in kN, transmitted through the stiffener connection to the PSM taken equal to:

$$W = \frac{P_1 s_1\left(S_1 - \frac{s_1}{2000}\right) + P_2 s_2\left(S_2 - \frac{s_2}{2000}\right)}{2\sin\varphi_{w1}\sin\varphi_{w2}} 10^{-3}$$

P_1, P_2 : Design pressure applied on the stiffener for the design load set being considered, in kN/m^2, on each side of the considered connection. For bottom slamming or bow impact loads, P_1 and P_2 are the design pressure as defined in Ch 4, Sec 5, [3.2] and [3.3] respectively.

S_1, S_2: Spacing between the considered and the adjacent PSM on each side of the considered connection, in m.

s_1, s_2: Spacing of the stiffener, in mm, on each side of the considered connection.

α_a : Panel aspect ratio, not to be taken greater than 0.25.

$$\alpha_a = \frac{s}{1000S}$$

$$S = \frac{S_1 + S_2}{2}$$

$$s = \frac{s_1 + s_2}{2}$$

φ_{w1} : Angle between primary supporting member and attached plating, in deg, as defined in Ch 3 , Sec 7, Symbols and Ch 10, Sec 1, Figure 5.

φ_{w2} : Angle between stiffener and attached plating, in deg, as defined in Ch 3, Sec 7, Symbols and Ch 3, Sec 7,Figure 14.

A_1 : Effective net shear area, in cm^2, of the connection, to be taken equal to:

$A_1 = A_{1d} + A_{1c}$

In case of a slit type slot connections area, A_1, is given by:

$A_1 = 2A_{1d}$

In case of a typical double lug or collar plate connection area, A_1, is given by:

$A_1 = 2A_{1c}$

A_{1d} : Net shear connection area, in cm^2, excluding lug or collar plate, as given by:

$A_{1d} = l_d\, t_w\, 10^{-2}$

l_d : Length of direct connection between stiffener and PSM web, in mm.

t_w : Net web thickness of the primary supporting member, in mm.

A_{1c} : Net shear connection area, in cm^2, with lug or collar plate, given by:

$A_{1c} = f_1\, l_c\, t_c\, 10^{-2}$

l_c : Length of connection between lug or collar plate and PSM, in mm.

t_c : Net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent PSM web, in mm.

f_1 : Shear stiffness coefficient, taken as:

$f_1 = 1.0$, for stiffeners of symmetrical cross section.

$f_1 = 140/w$, not to be taken greater than 1.0, for stiffeners of asymmetrical cross section.

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Figure 8.

A_w : Effective net cross sectional area, in cm^2, of the PSM web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 9. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_w is to be measured at the throat of the connection, as shown in Figure 9.

f_c : Collar load factor taken equal to:

For intersecting stiffeners of symmetrical cross section:

$f_c = 1.85$ for $A_w \leq 14$

$f_c = 1.85 - 0.0441(A_w - 14)$ for $14 < A_w \leq 31$

$f_c = 1.1 - 0.013(A_w - 31)$ for $31 < A_w \leq 58$

$f_c = 0.75$ for $A_w > 58$

For intersecting stiffeners of asymmetrical cross section:

$$f_c = 0.68 + 0.0172 \frac{l_s}{A_w}$$

ls : Connection length equal to:

For a single lug or collar plate connection to the PSM:

$l_s = l_c$

For a single sided direct connection to the PSM:

$l_s = l_d$

In the case of a lug or collar plus a direct connection:

$l_s = 0.5\ (l_c + l_d)$

5.2.3

The load, W_2, in kN, transmitted through the PSM web stiffener is to be taken as:

- If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_\alpha - \frac{A_1}{4 f_c A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:

$W_2 = 0$

The values of A_w, A_{wc} and A_1 are to be such that the calculated stresses satisfy the following criteria:

- For the connection to the PSM web stiffener not in way of the weld: $\sigma_w \leq \sigma_{perm}$
- For the connection to the PSM web stiffener in way of the weld: $\sigma_{wc} \leq \sigma_{perm}$
- For the shear connection to the PSM web: $\tau_w \leq \tau_{perm}$

where:

W : Load, in kN, as defined in [5.2.2].

f_c : Collar load factor as defined in [5.2.2].

α_a : Panel aspect ratio, as defined in [5.2.2].

A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].

A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

w : Direct stress, in N/mm^2, in the PSM web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10 W_2}{A_w}$$

σ_{wc} : Direct stress, in N/mm^2, in the PSM web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10 W_2}{A_{wc}}$$

τ_w : Shear stress, in N/mm^2, in the shear connection to the PSM web:

$$\tau_w = \frac{10 W_1}{A_1}$$

A_{wc} : Effective net area, in cm^2, of the PSM web stiffener in way of the weld as shown in Figure 9.

σ_{perm} : Permissible direct stress given in Table 1 for AC-S ,AC-SD and AC-I, in N/mm^2.

τ_{perm} : Permissible shear stress given in Table 1 for AC-S , AC-SD and AC-I, in N/mm^2.

5.2.4
Where a backing bracket is fitted in addition to the PSM web stiffener, it is to be aligned with the web stiffener. The arm length of the backing bracket is not to be less than the depth of the web stiffener. The net cross sectional area through the throat of the bracket is to be included in the calculation of A_w as shown in Figure 9.

5.2.5
Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are not permitted in the cargo hold region.

5.2.6
Where built-up stiffeners have their face plate welded to the side of the web, a symmetrical arrangement of connection to the PSM is to be fitted. This may be achieved by fitting backing brackets on the opposite side of the PSM or bulkhead. In way of the cargo hold region, the PSM web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

5.2.7
Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener, but not connected to it, the offset PSM web stiffener is to be located in close proximity to the slot edge as shown in Figure 10. The ends of the offset web stiffeners are to be suitably tapered and softened.

ISC 5.2.7a Alternative arrangements are to be based on their ability to transmit load with equivalent effectiveness, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

Permissible stresses for connection between stiffeners and PSMs

Table 1

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set			Acceptance criteria set		
	AC-S	AC-SD	AC-I	AC-S	AC-SD	AC-I
PSM web stiffener	$0.83R_{eH}$ (2)	R_{eH}	R_{eH}	-	-	-
PSM web stiffener to intersecting stiffener in way of weld connection: • Double continuous fillet • Partial penetration weld	$0.58R_{eH}$ (2) $0.83R_{eH}$ (1)(2)	$0.7R_{eH}$ (2) R_{eH} (1)	R_{eH} R_{eH}	- -	- -	- -
PSM stiffener to intersecting stiffener in way of lapped welding	$0.50R_{eH}$	$0.60R_{eH}$	R_{eH}	-	-	-
Shear connection including lugs or collar plates: • Single sided connection • Double sided connection	- -	- -	- -	$0.71\tau_{eH}$ $0.83\tau_{eH}$	$0.85\tau_{eH}$ τ_{eH}	τ_{eH} τ_{eH}

(1) The root face is not to be greater than one third of the gross thickness of the PSM stiffener.
(2) Permissible stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the PSM web stiffener.

5.2.8
The size of the fillet welds is to be calculated according to Ch 12, Sec 3, [2.5] based on the weld factors given in Table 2. For the welding in way of the shear connection the size is not to be less than that required for the PSM web plate for the location under consideration.

Weld factors for connection between stiffeners and PSMs Table 2

Item	Acceptance criteria	Weld factor
PSM stiffener to intersecting stiffener	AC-S AC-SD AC-I	$0.6\sigma_{wc}/\sigma_{perm}$ not to be less than 0.38
Shear connection inclusive of lug or collar plate	AC-S AC-SD AC-I	0.38
Shear connection inclusive of lug or collar plate, where the web stiffener of the PSM is not connected to the intersection stiffener	AC-S AC-SD AC-I	$0.6\ \tau_w/\tau_{perm}$ not to be less than 0.44

Note 1:
τ_w : Shear stress, in N/mm^2, as defined in [5.2.3].
σ_{wc} : Stress, in N/mm^2, as defined in [5.2.3].
τ_{perm} : Permissible shear stress, in N/mm^2, see Table 1.
σ_{perm} : Permissible direct stress, in N/mm^2, see Table 1.
W : Load, in kN, as defined in [5.2.2].
A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].
A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

6 OPENINGS

6.1 Openings and scallops in stiffeners

6.1.1

Figure 11 shows examples of air holes, drain holes and scallops. In general, the ratio of a/b, as defined in Figure 11, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

6.1.2

Openings and scallops are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration, measured along the length of the stiffener toward the mid-span and 50 mm measured along the length in the opposite direction, see Figure 12. In areas where the shear stress is less than 60 percent of the permissible stress, alternative arrangements may be accepted.

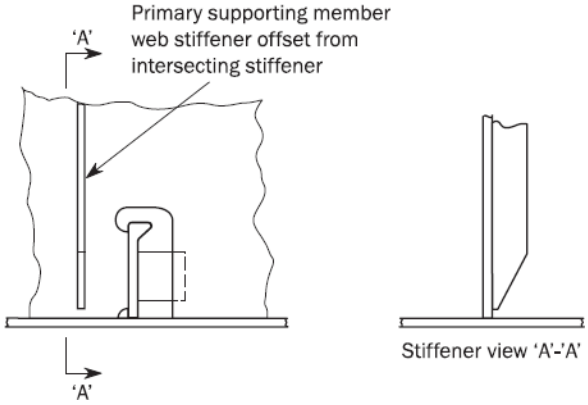
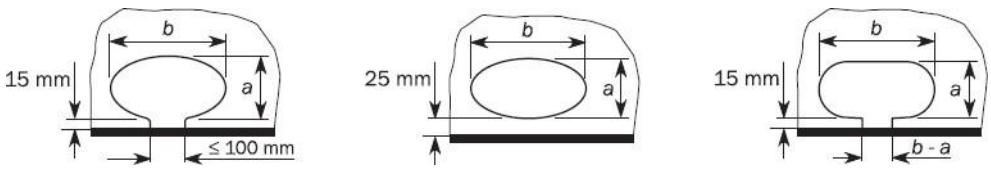


Figure 10 Offset PSM web stiffeners



The details shown in this figure are for guidance and illustration only.

Figure 11 Examples of air holes, drain holes and scallops

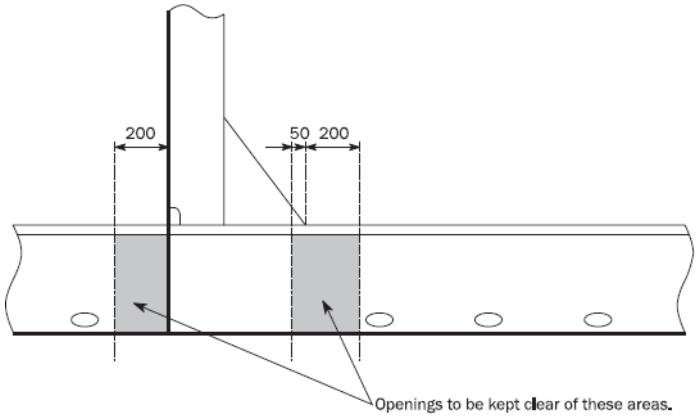


Figure 12 Location of air and drain holes

6.1.3

Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in Figure 11, are not permitted in stiffeners contributing to the longitudinal strength. For other stiffeners, closely spaced scallops/drain holes are not permitted within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, cut clear of the welds.

6.2 *Openings in primary supporting members*

6.2.1 General

Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

Examples of high stress areas include:

- Vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end.
- Floors or double bottom girders close to their span ends.
- Primary supporting member webs in way of end bracket toes.
- Above the heads and below the heels of pillars.

Where openings are arranged, the shape of openings is to be such that the stress concentration remains within acceptable limits.

Openings are to be well rounded with smooth edges.

6.2.2 *Manholes and lightening holes*

Web openings as indicated below do not require reinforcement

- In single skin sections, having depth not exceeding 25% of the web depth and located so that the edges are not less than 40% of the web depth from the faceplate.
- In double skin sections, having depth not exceeding 50% of the web depth and located so that the edges are well clear of cut outs for the passage of stiffeners.

The length of openings is not to be greater than:

- At the mid-span of primary supporting members: the distance between adjacent openings.
- At the ends of the span: 25% of the distance between adjacent openings.

For openings cut in single skin sections, the length of opening is not to be greater than the web depth or 60% of the stiffener spacing, whichever is greater.

The ends of the openings are to be equidistant from the cut outs for stiffeners.

Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

Openings not complying with this requirement are to be reinforced according to [6.2.3].

6.2.3 *Reinforcements around openings*

Manholes and lightening holes are to be stiffened according to this requirement, except where alternative arrangements are demonstrated as satisfactory, in accordance with the analysis methods described in Ch7.

On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, see Figure 13.

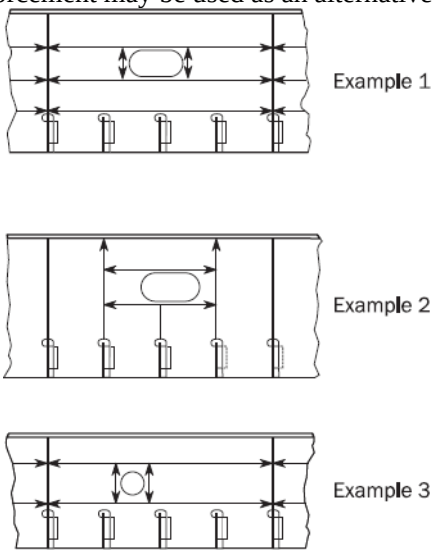


Figure 13 Web plate with openings

In the case of large openings in the web of PSMs (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in PSMs are to be considered for the reinforcement of these openings.

Where no FE analysis is performed, this may be carried out by assigning an equivalent net shear sectional area to the PSM obtained, in cm^2, according from the following formula:

$$A_{s-n50} = \frac{A_{1-n50}}{1+\frac{32 l_{shr}^2 A_{1-n50}}{I_{1-n50}}} + \frac{A_{2-n50}}{1+\frac{32 l_{shr}^2 A_{2-n50}}{I_{2-n50}}}$$

where:

$I_{1\text{-}n50}$, $I_{2\text{-}n50}$: Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating.

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$: Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut out for the passage of the ordinary stiffeners, if any.

l_{shr} : Shear span, in m, of deep webs (1) and (2) as defined in Ch3, Sec 7, [1.1.2]. Deep web (1) and (2) are defined in Figure 14.

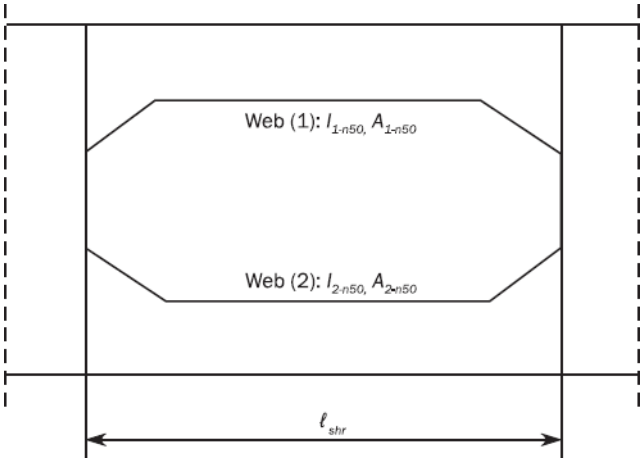


Figure 14 Large openings in the web of primary supporting members

6.3 Openings in the strength deck

6.3.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the ends of superstructures. Openings are to be located as far as practicable from high stress regions such as side shell platings, hatchway corners, or hatch side coamings.

6.3.2 *Small opening location*

Openings are generally to be located outside the limits as shown in Figure 15 in dashed area, defined by:

- The bent area of a rounded sheer strake, if any, or the side shell.
- $e = 0.25\ (B - b)$ from the edge of opening.
- $c = 0.07l + 0.1b$ or $0.25b$, whichever is greater.

where:

b : Width, in m, of the hatchway considered, measured in the transverse direction, see Figure 15.

l :Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Figure 15.

Transverse distance between the above limits and openings or between hatchways and openings as shown in Figure 15 is not to be less than:

- $g_2 = 2a_2$ for circular openings.
- $g_1 = a_1$ for elliptical openings.

Transverse distance between openings as shown in Figure 16 is not to be less than:

- $2\ (a_1 + a_2)$ for circular openings.
- $1.5\ (a_1 + a_2)$ for elliptical openings.

where:

a_1 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_2 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_3 : Longitudinal dimension of elliptical openings, or diameter of circular openings.

Longitudinal distance between openings is not to be less than:

- $(a_1 + a_3)$ for circular openings.
- $0.75\ (a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one.

If the opening arrangements do not comply with these requirements, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas, see Ch5, Sec 1, [1.2.11].

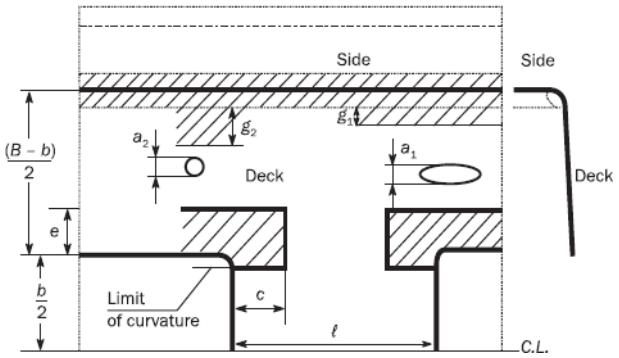


Figure 15 Position of openings in strength deck

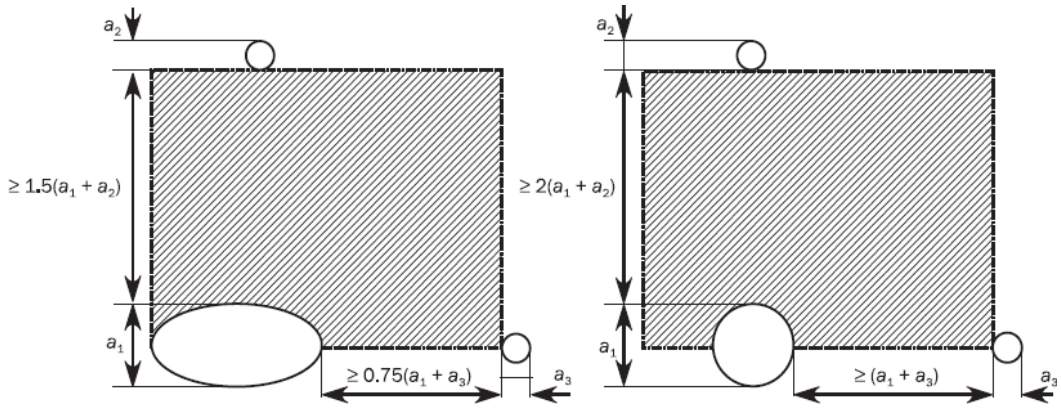


Figure 16 Elliptical and circular openings in strength deck

7 DOUBLE BOTTOM STRUCTURE

7.1 General

7.1.1 Framing system

For ships greater than 120 m in length, the bottom shell, the inner bottom and the sloped bulkheads of hopper tanks, if any, are to be longitudinally framed within the cargo hold region. Where it is not practicable to apply the longitudinal framing system to fore and aft parts of the cargo hold region due to the hull form, transverse framing may be accepted on a case-by-case basis subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of changes to the framing system.

7.1.2 *Variation in height of double bottom*

Any variation in the height of the double bottom is to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors. Where such arrangement is not possible, suitable longitudinal structures such as partial girders, longitudinal brackets, fitted across the knuckle are to be arranged.

7.1.3 *Breadth of inner bottom*

Breadth of inner bottom, in m, is to be measured at mid-length of the cargo hold as shown in Figure 17.

7.1.4 *Drainage of tank top*

For ships designed to carry solid cargoes, effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half height of the double bottom.

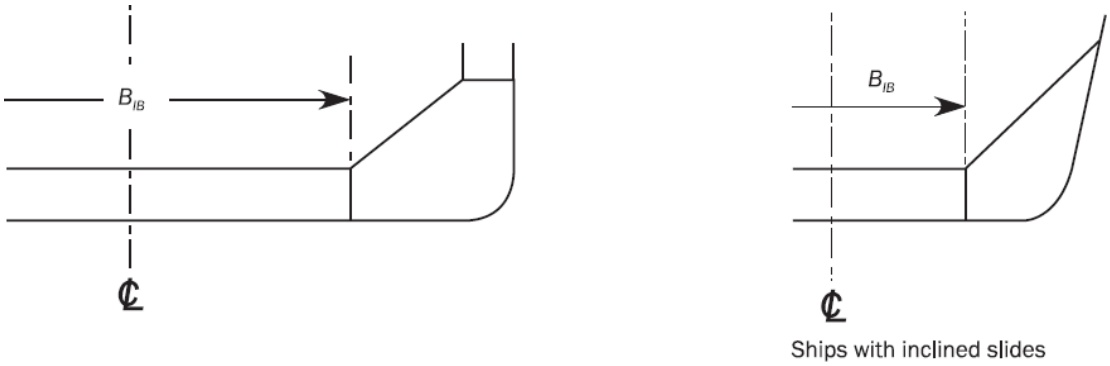


Figure 17 Breadth of inner bottom

7.1.5 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the plating.

7.1.6 *Duct keel*

Where a duct keel is arranged, the centre girder may be replaced by two girders spaced, no more than 3 m apart. Otherwise, for a spacing wider than 3 m, the two girders are to be provided with support of adjacent structure and subject to the Society's approval.

The structures in way of the floors are to provide sufficient continuity of the latter.

7.2 *Keel plate*

7.2.1

Keel plating is to extend over the flat of bottom for the full length of the ship.

The width of the keel, in m, is not to be less than $0.8 + L/200$, without being taken greater than 2.3 m.

7.3 *Girders*

7.3.1 Centre girder

When fitted, the centre girder is to extend within the cargo hold region and is to extend forward and aft as far as practicable. Structural continuity of the centre girder is to be maintained within the full length of the ship.

Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the centre girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within $0.25\,B$ from the centreline.

7.3.2 *Side girders*

The side girders are to extend within the parallel part of the cargo hold region and are to extend forward and aft of the cargo hold region as far as practicable.

7.4 *Floors*

7.4.1 Web stiffeners

Floors are to be provided with web stiffeners in way of longitudinal ordinary stiffeners. Where the web stiffeners are not welded to the longitudinal stiffeners, design standard as given in Ch9, Sec 6, [2] applies unless fatigue strength assessment for the cut out and connection of longitudinal stiffener is carried out.

7.5 *Bilge keel*

7.5.1 Material

The material of the bilge keel and ground bar is to be of the same yield stress as the material to which they are attached.

In addition, when the bilge keel extends over a length more than 0.15 *L*, the material of the bilge keel and ground bar is to be of the same grade as the material to which they are attached.

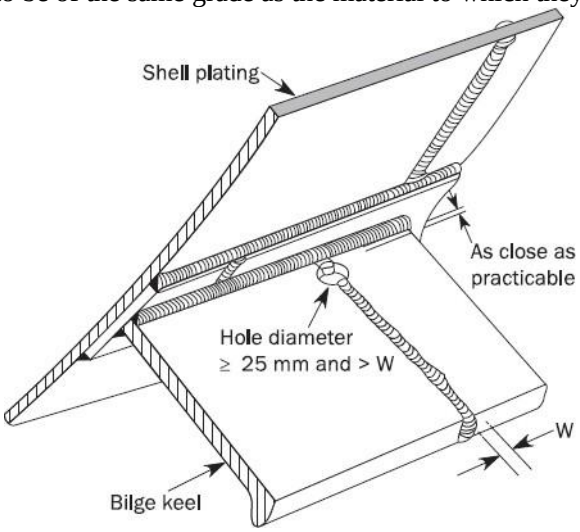
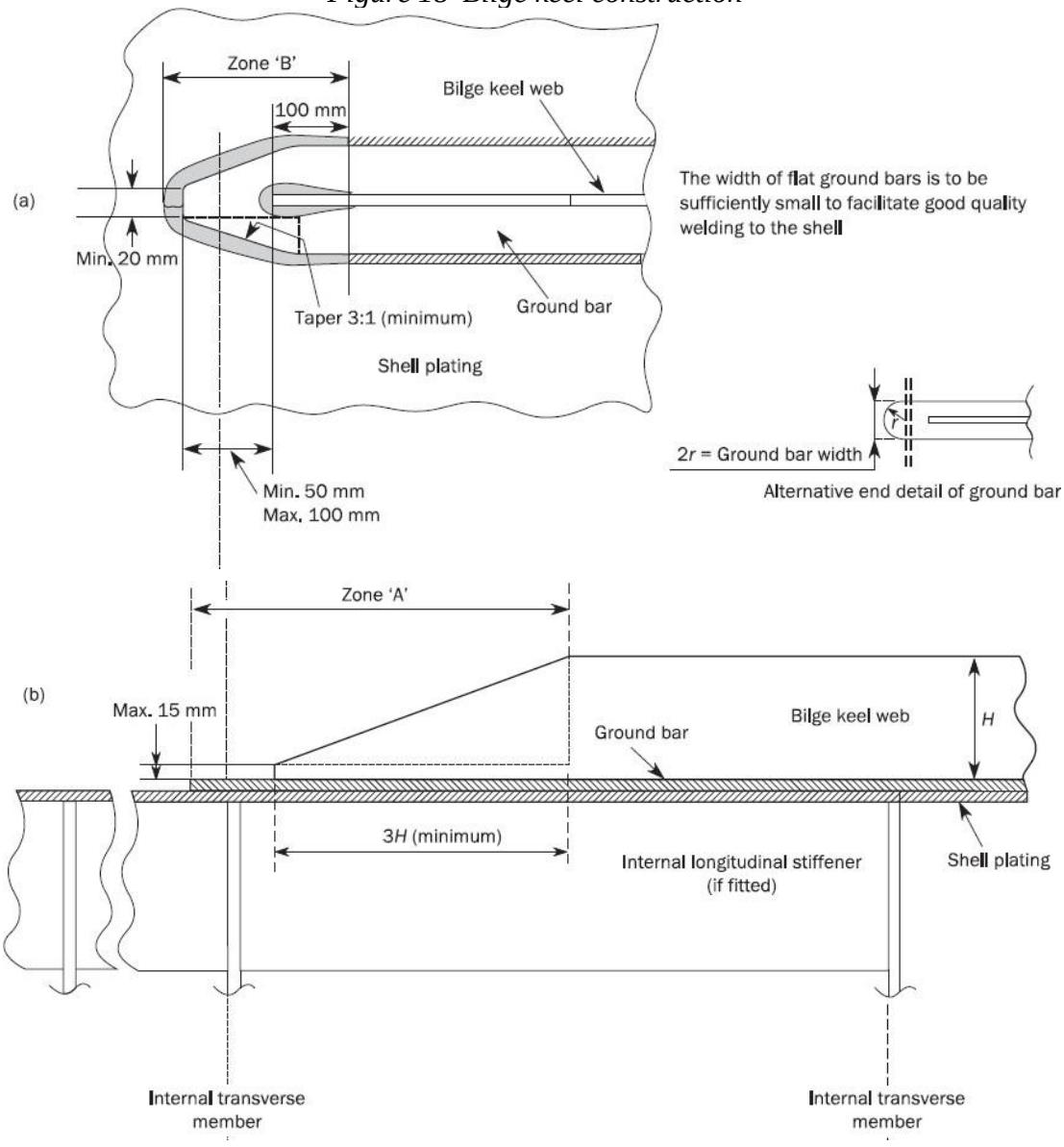


Figure 18 Bilge keel construction



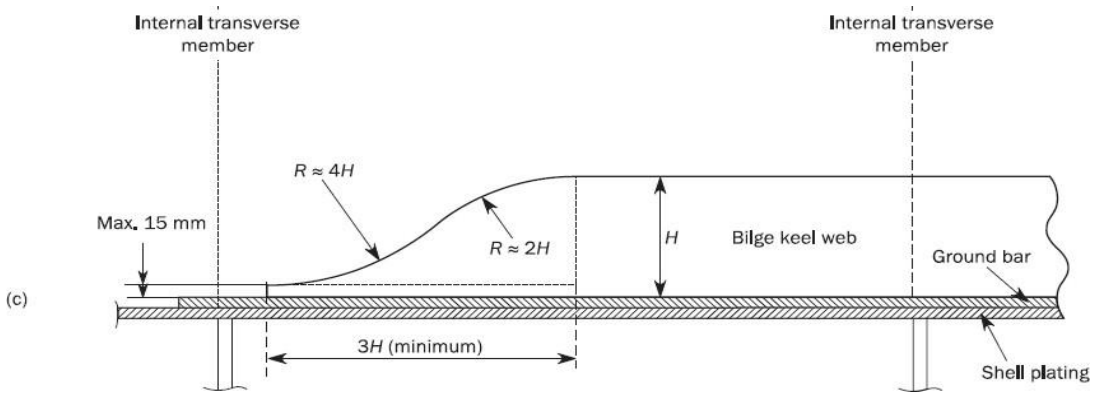


Figure 19 Bilge keel end design

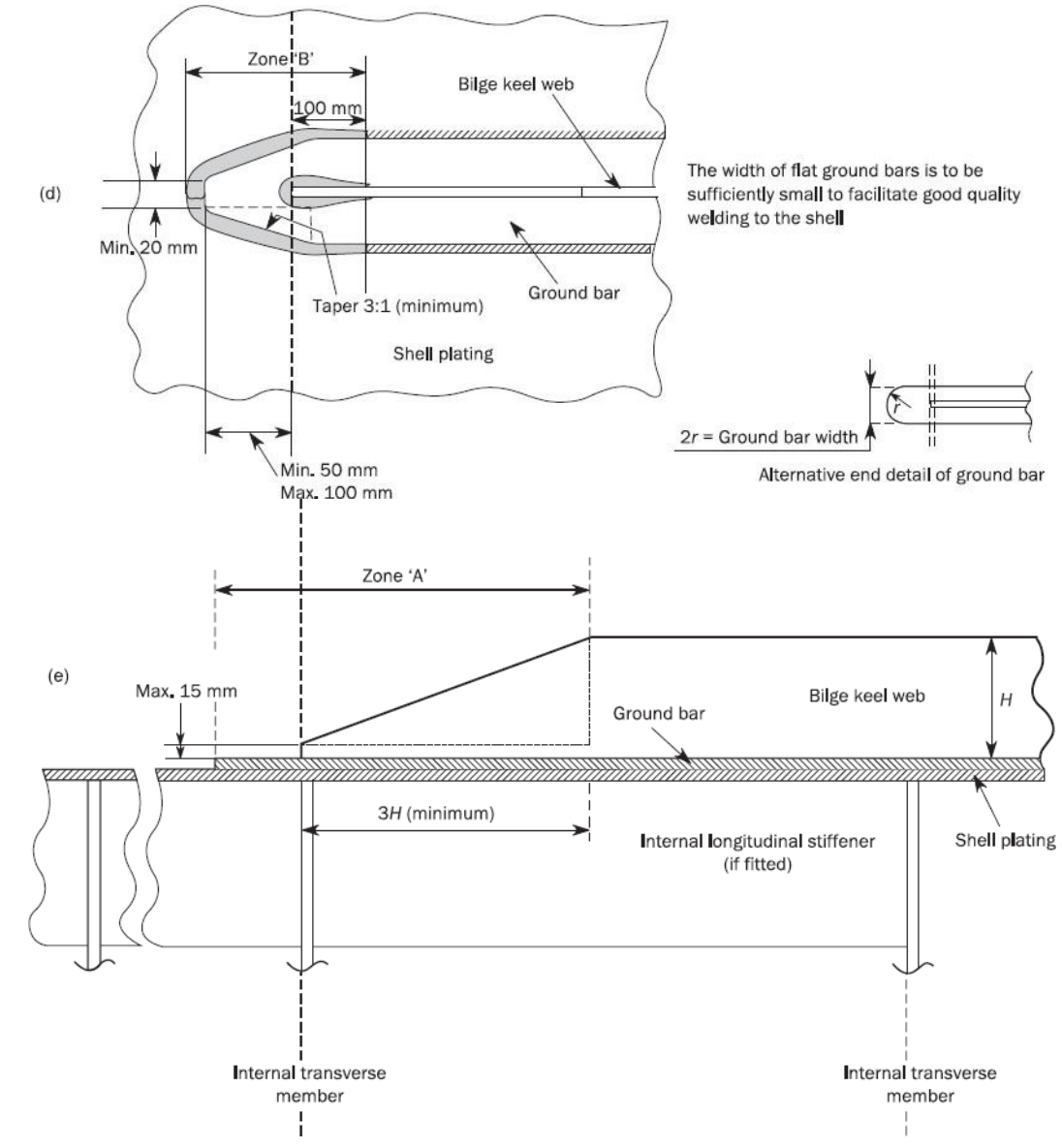


Figure 20 Bilge keel end design (continued)

7.5.2 Design

The design of single web bilge keels is to be such that failure to the web occurs before failure of the ground bar. This may be achieved by ensuring the web thickness of the bilge keel does not

exceed that of the ground bar.

Bilge keels of a different design, from that shown in Figure 18, are to be specially considered by the Society.

ISC 7.5.2a Where bilge keels are fitted, they are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating and the ground bar or doubler may be welded directly to the shell and kept continuous. Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating.

7.5.3 *Ground bars*

Bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Figure 18 and Figure 19. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14mm, whichever is the lesser.

7.5.4 *End details*

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see items (a), (b), (d) and (e) in Figure 19/Figure 20. Rounded ends are to be as shown in item (c) of Figure 19. Cut-outs on the bilge keel web, within zone 'A' (see items (b) and (e) of Figure 19/Figure 20) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar, see items (a) and (d) of Figure 19/Figure 20.

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- Transverse support member is to be fitted at mid length between the end of the bilge keel web and the end of the ground bar, see items (a), (b) and (c) of Figure 19.
- Longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone 'A' (see items (b) and (e) of Figure 19/Figure 20).

Alternative end arrangements may be accepted, provided that they are considered equivalent.

ISC 7.5.4a Other types of end detail design may be accepted provided that bilge keels and flat bars are gradually tapered at their ends and equivalent to 7.5.4.

7.6 *Docking*

7.6.1 General

The drydocking arrangement itself is not covered in these Rules.

The bottom structure is to withstand the forces imposed by drydocking the ship.

7.6.2 *Docking brackets*

Docking brackets connecting the centreline girder to the bottom plating, are to be connected to the adjacent bottom longitudinals.

8 DOUBLE SIDE STRUCTURE

8.1 General

8.1.1

Side shell and inner hull bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be longitudinally framed. Alternative framing arrangements are to be specially considered by the Society.

ISC 8.1.1a Alternative types of framing are to be based on compliance with the requirements for strength and structural arrangements in this PART, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

8.1.2
Where the double side space of bulk carriers is void, the structural members bounding this space are to be structurally designed as a water ballast tank. In such a case the corresponding air pipe is considered as extending 0.76 m above the freeboard deck at side. For corrosion addition, the space is to be considered as a void space.

8.2 *Structural arrangement*

8.2.1 Primary supporting members

Double side web frames are to be fitted in line with web frames in hopper tanks. In addition, double side web frames are to be aligned with web frames or large brackets in topside tanks.

Vertical primary supporting members are to be fitted in way of hatch end beams of bulk carriers or similar large deck opening supporting transverse structure.

In general, horizontal side stringers are to be fitted aft of the collision bulkhead, up to 0.2 *L* aft of the fore end, in line with fore peak stringers.

8.2.2 *Transverse stiffeners*

Transverse stiffeners on side shell and inner side, where fitted, are to be continuous or fitted with bracket end connections within the height of the double side. The transverse stiffeners are to be effectively connected to stringers. At their upper and lower ends, shell and inner side transverse stiffeners are to be connected by brackets to supporting stringer plates.

8.2.3 *Longitudinal stiffeners*

Longitudinal stiffeners on side shell and inner side, where fitted, are to be continuous within the length of the parallel part of the cargo hold region. They are to be fitted with soft toe brackets in way of transverse bulkheads aligned with cargo hold bulkheads and are to be effectively connected to transverse web frames of the double side structure.

Longitudinal framing of the side shell is to extend outside the cargo hold region as far forward as practicable.

8.2.4 *Sheer strake*

Sheer strakes are to have breadths not less than 0.8+ *L*/200 m, measured vertically, but need not be greater than 1.8 m.

The heer strake may be either welded to the stringer plate or rounded.

If the sheer strake is rounded, its radius, in mm, is to be not less than $17t_s$, where t_s is the net thickness, in mm, of the sheer strake.

The upper edge of the welded sheer strake is to be rounded smooth and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake.

The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6 *L* amidships.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures is to be designed to avoid any discontinuities.

8.2.5 *Plating connection*
Connection between the inner hull plating and the inner bottom plating is to be designed such that stress concentration is avoided.

The connections of hopper tanks plating with inner hull and with inner bottom are to be supported by a primary supporting member.

9 DECK STRUCTURE
9.1 Structural arrangement
9.1.1 Framing system
Deck areas contributing to the longitudinal strength are to be longitudinally framed.

9.1.2 *Stringer plate*
Stringer plates are to have breadths not less than $0.8 + L/200$ m, measured parallel to the deck, but need not be greater than 1.8 m.

Rounded stringer plates, where adopted, are to comply with the requirements in [8.2.4].

9.1.3 *Connection of deckhouses and superstructures*
Connection of deckhouses and superstructures to the strength deck are to be designed such that loads are transmitted into the under deck supporting structure.

9.2 *Deck scantlings*
9.2.1
The web depth of deck stiffeners is not to be less than 60 mm.

The web depth of PSMs is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is the bending span as defined in Ch3, Sec 7 or in case of a grillage structure, the distance between connections to other PSMs.

10 BULKHEAD STRUCTURE
10.1 Application
10.1.1
The requirements of this article apply to longitudinal and transverse bulkheads, which may be plane or corrugated.

10.2 *General*
10.2.1
The web height of vertical PSMs on bulkheads may be gradually tapered from bottom to deck.

10.2.2
Bulkheads are to be stiffened in way of deck girders.

10.2.3
Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars that would be located at the same position.

10.2.4
Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way of the connection are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

10.3 *Plane bulkheads*
10.3.1 General
Plane bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads are made of horizontal stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads are made of vertical stiffeners supported by horizontal stringers, if needed.

The bulkhead stiffener webs of hopper and topside tank watertight bulkheads are to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.

Floors are to be fitted in the double bottom in line with the plane transverse bulkhead.

10.3.2 *End connection of stiffeners*

The crossing of stiffeners through a watertight bulkhead is to be watertight.

End connections of stiffeners are to be bracketed. For isolated areas of the ship where bracketed end connections cannot be applied due to hull lines, other arrangements including sniped ends are acceptable.

10.3.3 *Sniped end of stiffener*

Sniped ends may be used on bulkheads subject to hydrostatic pressure provided they comply with [3.4].

10.4 *Corrugated bulkheads*

10.4.1 General

For ships of 18 m moulded depth and above, the transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For ships of 16 m moulded depth and above, the transverse vertically corrugated watertight bulkheads subject to liquid pressure, e.g. tank bulkheads and ballast hold bulkheads, are to be fitted with a lower stool, and generally with an upper stool below deck.Otherwise corrugations may extend from inner bottom to deck.

10.4.2 *Construction*

The main dimensions $b_{f\text{-}cg}$, R, $b_{w\text{-}cg}$, d_{cg}, t_f, t_w, s_{cg} of corrugated bulkheads are defined in Figure 21.
The corrugation angle φ is not to be less than 55°.
When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

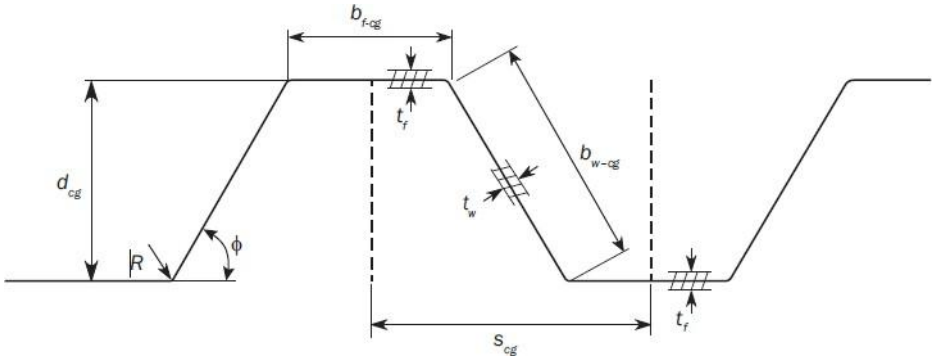


Figure 21 Dimensions of a corrugated bulkhead

10.4.3 Corrugated bulkhead depth

The depth of the corrugation, d, in mm, is not to be less than:

$$d_{cg} = \frac{1000 l_c}{C}$$

where:

l_c : Mean span of considered corrugation, in m, as defined in [10.4.5].

C : Coefficient to be taken as:

C = 15 for tank and water ballast cargo hold bulkheads.

C = 18 for dry cargo hold bulkheads.

10.4.4 *Actual section modulus of corrugations*

The net section modulus of a corrugation may be obtained, in cm3, from the following formula:

$$Z = \left[\frac{d_{cg}\left(3b_{f-cg}t_f + b_{w-cg}t_w\right)}{6} \right] 10^{-3}$$

where:

t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in Figure 21.

d_{cg}, $b_{f\text{-}cg}$, $b_{w\text{-}cg}$: Dimensions of the corrugation, in mm, shown in Figure 21.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$Z = 0.5 b_{f\text{-}cg}\, t_f\, d_{cg} 10^{-3}$

10.4.5 *Span of corrugations*

The span l_C of the corrugations is to be taken as the distance shown in Figure 22.

For the definition of l_C, the bottom of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, for non rectangular stool.
- 2 times the depth of corrugation, for rectangular stool.

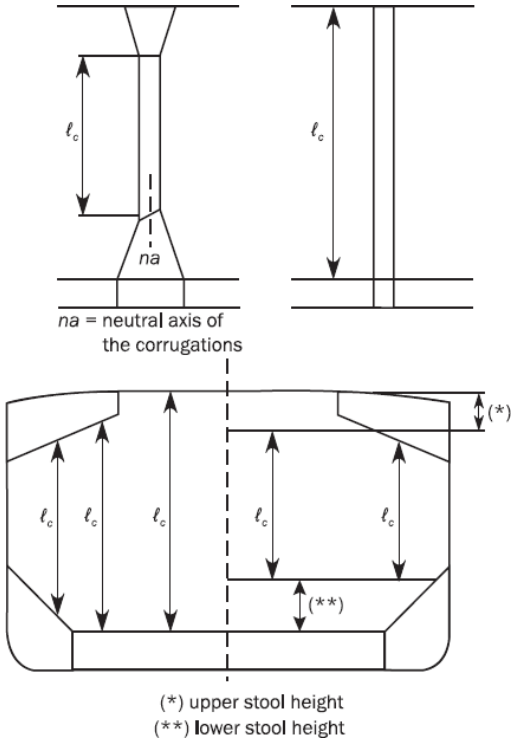


Figure 22 Span of the corrugations

10.4.6 Structural arrangements

Where corrugated bulkheads are cut in way of primary supporting members, corrugations on each side of the primary member are to be aligned with each other.

10.4.7 *Bulkhead end supports*

The strength continuity of corrugated bulkheads is to be maintained at the ends of corrugations.

Where a bulkhead is provided with a lower stool, floors or girders are to be fitted in line with both sides of the lower stool. Where a bulkhead is not provided with a lower stool, floors or girders are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead.

The supporting floors or girders are to be connected to each other by suitably designed shear plates.

At deck, if no upper stool is fitted, transverse or longitudinal stiffeners are to be fitted in line with the corrugation flanges.

When the corrugation flange connected to the adjoining boundary structures (i.e. inner hull, side shell, longitudinal bulkhead, trunk, etc) is smaller than 50% of the width of the typical corrugation flange, an advanced analysis of the connection is required.

10.4.8 *Bulkhead stools*

Stool side plating is to be aligned with the corrugation flanges.

10.4.9 *Lower stool*

The lower stool, when fitted, is to have a height in general not less than:

- 3 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures such as longitudinals or similar. Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

The distance *d* from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Figure 23.

The lower part of the stool side plates is to be in line with double bottom floors or girders as the case may be, and the stool bottom is to have a width not less than:

- 2.5 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

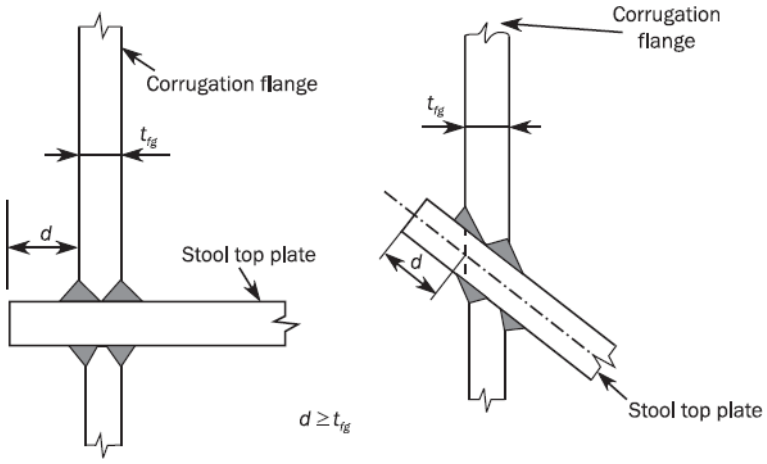


Figure 23 Permitted distance, d, from the edge of the stool top plate to the surface of the corrugation flange

The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

10.4.10 *Upper stool*

The upper stool, when fitted, is to have a height:

- Not less than two times the corrugation depth, for bulk carriers.
- At least one corrugation depth, for oil tankers.

Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder or at the inner hull as applicable. Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams.

The upper stool of a transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams. The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools of bulk carriers is to have a width not less than twice the depth of corrugations. The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.5 *Non-tight bulkheads*

10.5.1 General

In general, openings in wash bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead. The area of non-tight bulkhead is the whole cross sectional area in one plane that covers the tank boundaries.

10.5.2 *Non-tight bulkheads not acting as pillars*

In general, the maximum spacing of stiffeners fitted on non-tight bulkheads not acting as pillars is to be:

- 0.9 m, for transverse bulkheads.
- Two frame spacings, with a maximum of 1.5 m, for longitudinal bulkheads.

The net thickness of bulkhead stiffener, in mm, is not to be less than:

$t = 3 + 0.015\ L_2$

The depth of bulkhead stiffener of flat bar type is in general not to be less than 1/12 of stiffener length.

A smaller depth of stiffener may be accepted based on calculations showing compliance with Ch10, Sec4, [2.2] and Ch8.

10.5.3 *Non-tight bulkheads acting as pillars*

Non-tight bulkheads acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- Two frame spacings, when the frame spacing does not exceed 0.75 m.
- One frame spacing, when the frame spacing is greater than 0.75 m.

Where non-tight bulkheads are corrugated, the depth of the corrugation is not to be less than 100 mm.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, 1/12 of stiffener length or the stiffener spacing, whichever is the smaller, is to comply

with the applicable requirements in Ch6, for the load being supported.

10.6 *Watertight bulkheads of trunks and tunnels 10.6.1*

Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

ISC 10.6.1a Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be in compliance with the requirements of Section3, Chapter 4, PART ONE of the Rules.

11 PILLARS

11.1 General

11.1.1

Pillars are to be fitted in the same vertical line wherever possible. If not possible, effective means are to be provided for transmitting their loads to the supports below. Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

11.1.2

Pillars are to be provided in line with the double bottom girder or as close thereto as practicable, and the structure above and below the pillars is to be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures are to be fitted as necessary to support the pillars.

11.1.3

Pillars provided in tanks are to be of solid or open section type.

Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

11.2 *Connections*

11.2.1

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Alternative arrangements for doubling plates may be accepted, provided that they are considered equivalent as deemed appropriate by the Society. Where the pillars are likely to be subjected to tensile loads, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.

The net thickness of doubling plates, when fitted, is to be not less than 1.5 times the net thickness of the pillar. Pillars are to be attached at their heads and heels by continuous welding.

ISC 11.2.1a Where heads or heels of pillars are secured by alternative arrangements for doubling plates, it is to be ensured that the force acting on heads or heels of pillars can be effectively transmitted and any abrupt change of transmitted force is to be avoided.

Section 7 STRUCTURAL IDEALISATION

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

φ_w : Angle, in deg, between the stiffener or primary supporting member web and the attached plating, see Figure 14 for stiffener and Ch 10, Sec 1, Figure 5 for primary supporting member. φ_w is to be taken equal to 90 deg if the angle is between 75 and 105 deg including 75 and 105 deg.
l_{bdg} : Effective bending span, in m, as defined in [1.1.2] for stiffeners and [1.1.6] for primary supporting members.
l_{shr} : Effective shear span, in m, as defined in [1.1.3] for stiffeners and [1.1.7] for primary supporting members.
l : Full length of stiffener or of primary supporting member, in m, between their supports.
s : Stiffener spacing, in mm, as defined in [1.2].
S : Primary supporting member spacing, in m, as defined in [1.2].
a : Length, in mm, of EPP as defined in [2.1.1].
b : Breadth, in mm, of EPP as defined in [2.1.1].
h_{stf} : Stiffener height, including the face plate, in mm.
t_p : Net thickness of attached plate, in mm.
t_w : Net web thickness, in mm. For bulb profiles, see [1.4.1].
b_f : Breadth of flange, in mm, see Ch 3, Sec 2, Figure 2. For bulb profiles, see [1.4.1].
t_f : Net thickness of flange, in mm.
PSM : Primary Supporting Member.
EPP : Elementary Plate Panel.
LCP : Load Calculation Point.

1 STRUCTURAL IDEALISATION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

1.1 Effective spans

1.1.1 General

Where arrangements differ from those defined in this article, span definition may be specially considered.

ISC 1.1.1a For the definition of a span where the structural arrangement is different from that defined in this Section, equivalence or substitution is to be, based on the geometrical characteristics of end brackets of stiffeners and primary supporting members, their end constraints and actual load-carrying capacity, granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

1.1.2 *Effective bending span of stiffeners*

The effective bending span l_{bdg} of stiffeners is to be measured as shown in Figure 1 for single skin structures and Figure 2 for double skin structures.

If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between PSMs unless a backing bracket is fitted, see Figure 1.

The effective bending span may be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted on the side opposite to that of the stiffener with respect to attached plating are not to be considered as effective in reducing the effective bending span.

In single skin structures, the effective bending span of a stiffener supported by a bracket or by a web stiffener on one side only of the primary supporting member web, is to be taken as the total span between primary supporting members as shown in item (a) of Figure 1. If brackets are fitted on both sides of the primary supporting member, the effective bending span is to be taken as in

items (b), (c) and (d) of Figure 1.

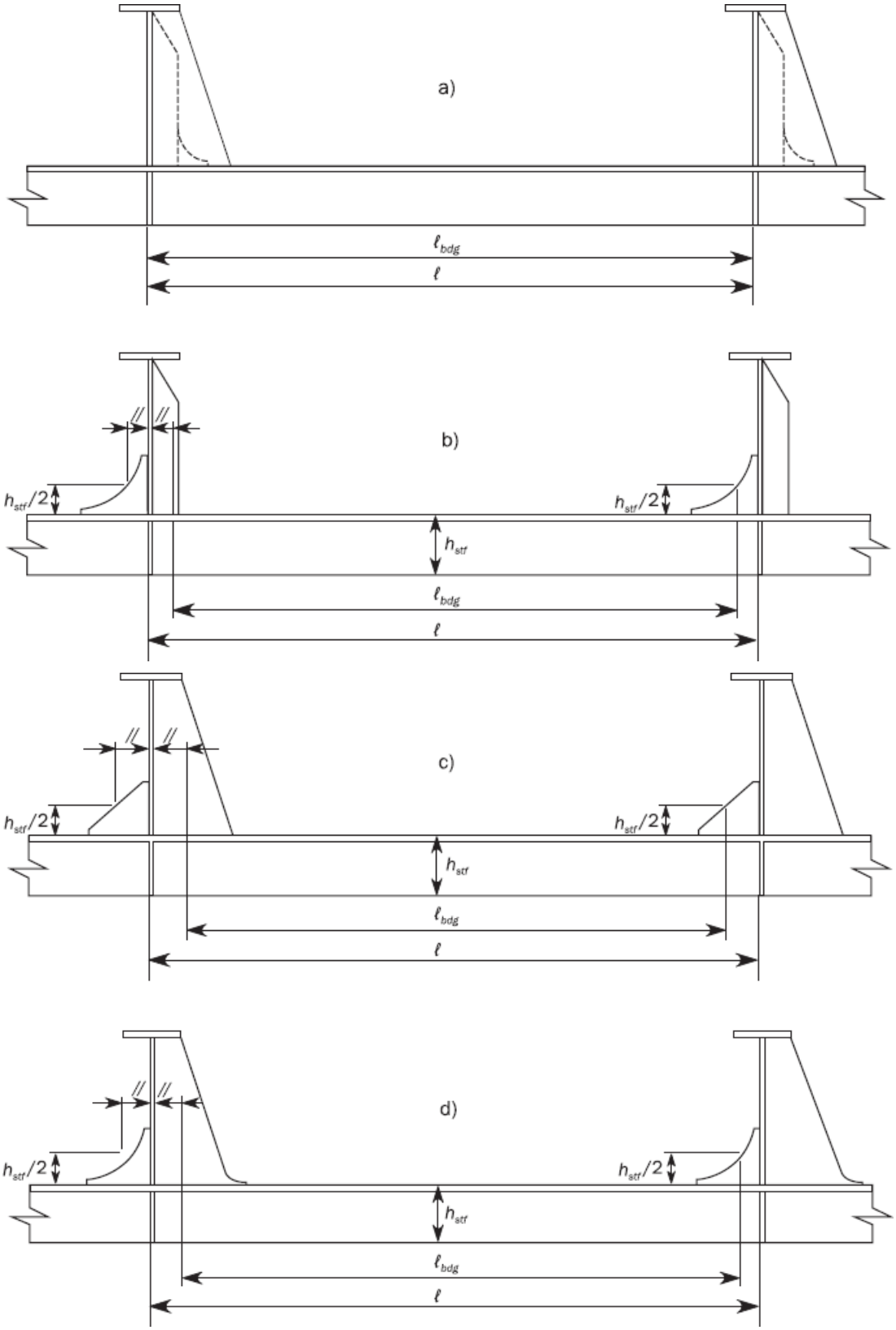


Figure 1 Effective bending span of stiffeners supported by web stiffeners (single skin construction)

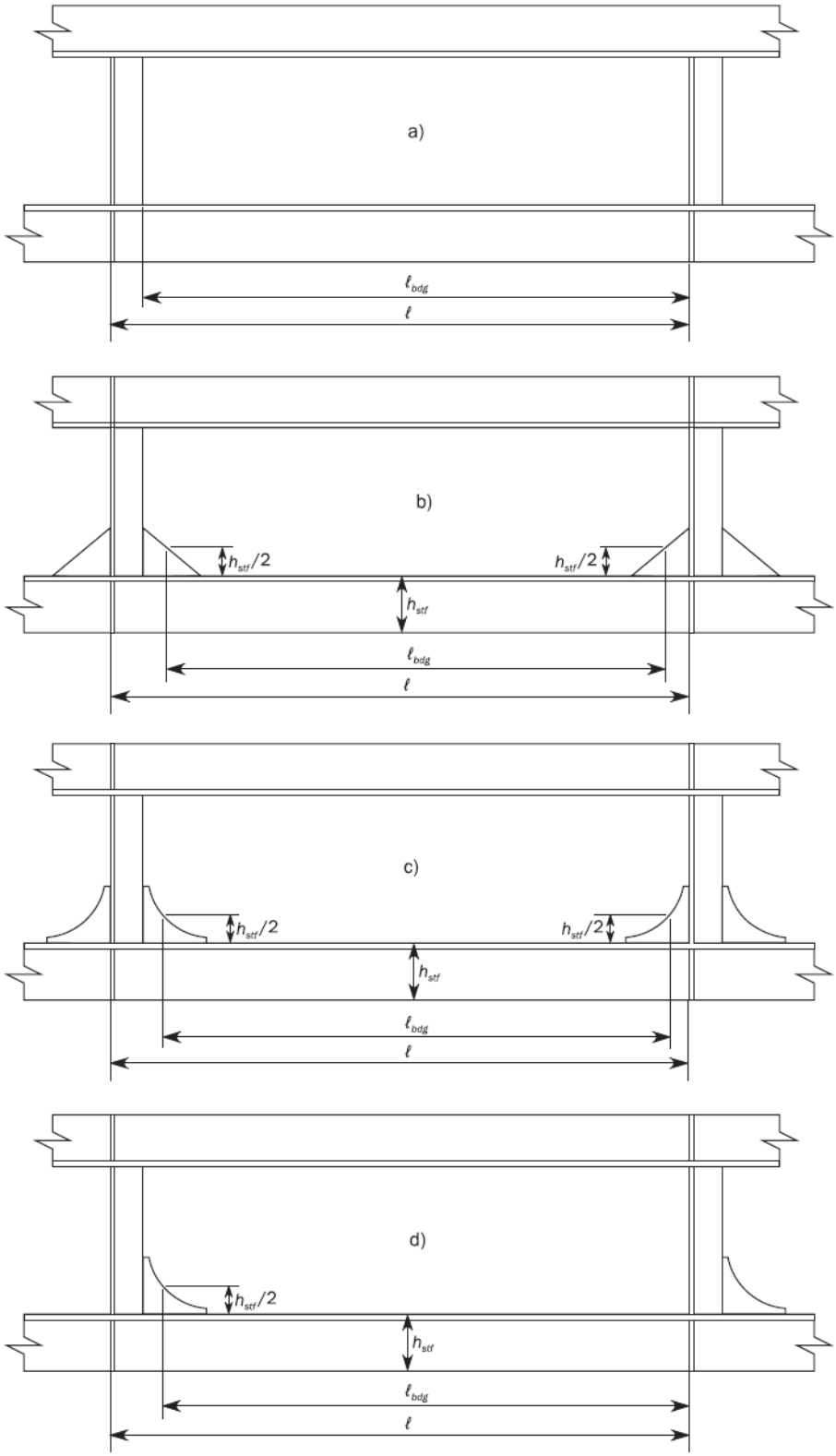


Figure 2 Effective bending span of stiffeners supported by web stiffeners (double skin construction)

Where the face plate of the stiffener is continuous al ong the edge of the bracket the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener see Figure 3.

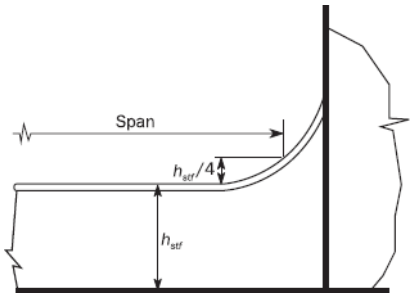


Figure 3 Effective bending span for local support members with continuous face plate along bracket edge

1.1.3 Effective shear span of stiffeners

The effective shear span, l_{shr} in m, of stiffeners is to be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

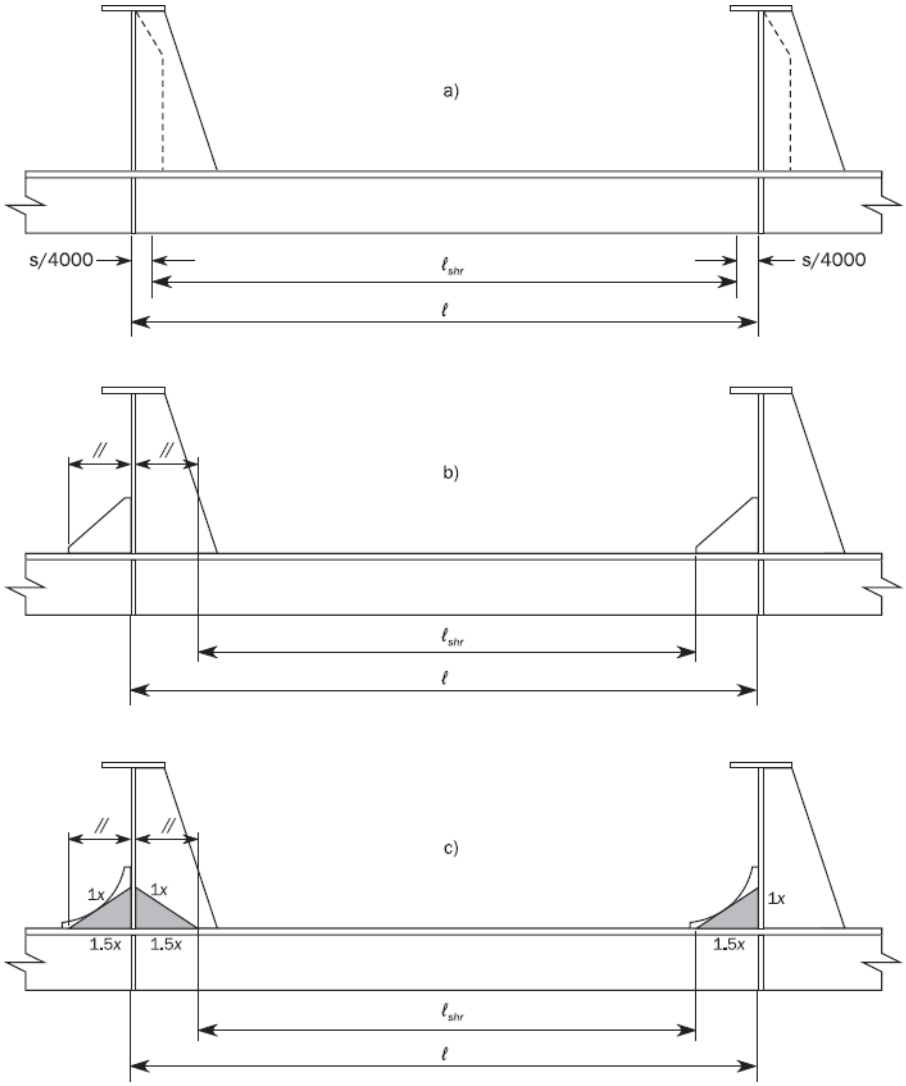


Figure 4 Effective shear span of stiffeners supported by web stiffeners (single skin construction)

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

Regardless of support detail, the full length of the stiffener may be reduced by a minimum of s/4000 m at each end of the member, hence the effective shear span l_{shr}, is not to be taken greater than:

$$l_{shr} \leq l - \frac{s}{2000}$$

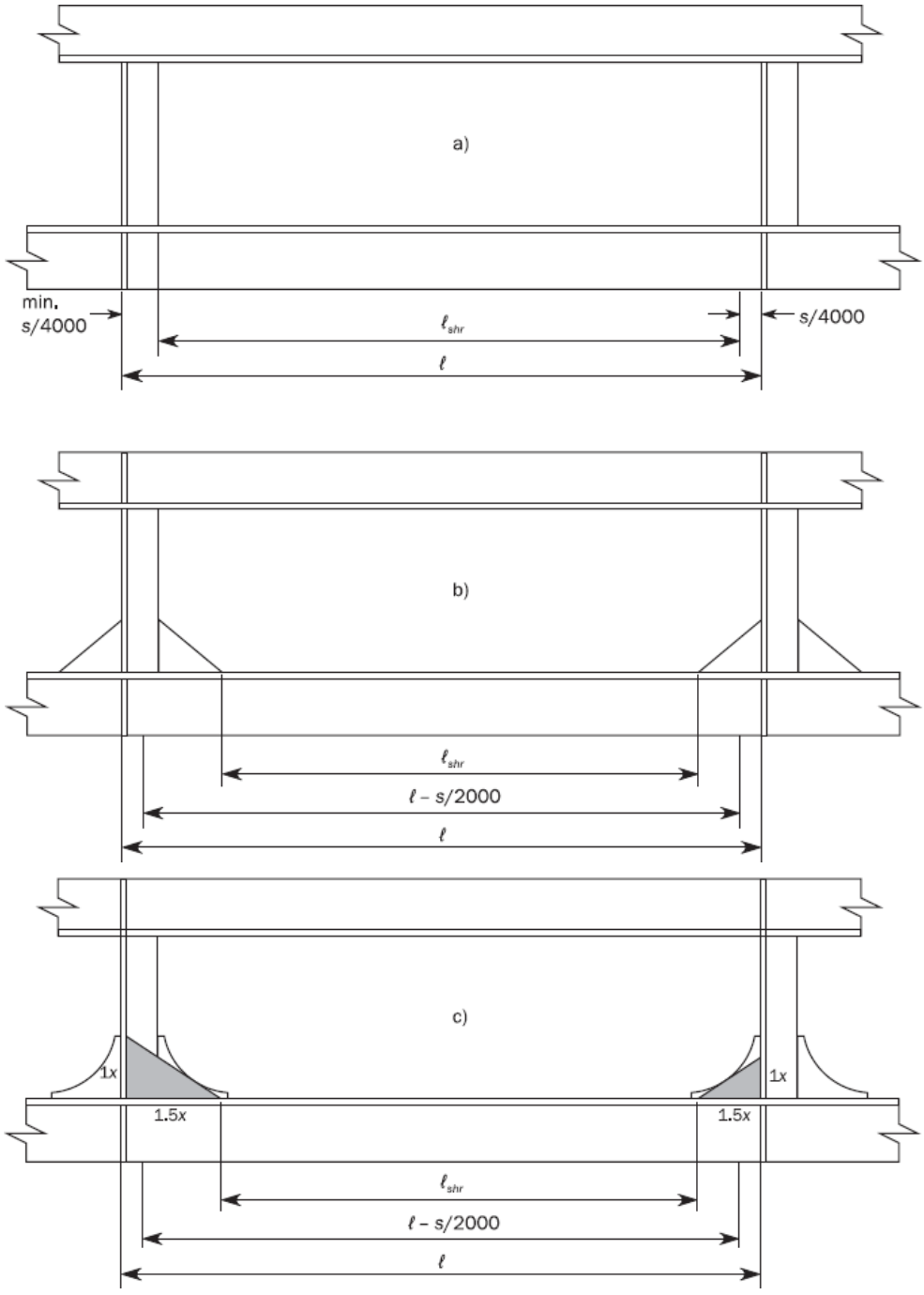


Figure 5 Effective shear span of stiffeners supported by web stiffeners (double skin construction)

For curved and/or long brackets (high length/height ratio), the effective bracket length is to be

taken as the maximum inscribed 1:1.5 right angled triangle as shown in item (c) of both Figure 4 and Figure 5.

Where the face plate of the stiffener is continuous along the curved edge of the bracket, the bracket length to be considered for determination of the span point location is not to be taken greater than 1.5 times the length of the bracket arm as shown in Figure 6.

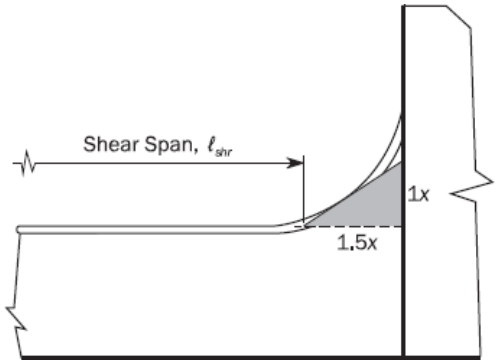


Figure 6 Effective shear span for local support members with continuous face plate along bracket edge

1.1.4 Effect of hull form shape on span of stiffeners

For curved stiffeners, the span is defined as the chord length between span points to be measured at the flange for stiffeners with a flange, and at the free edge for flat bar stiffeners. The calculation of the effective span is to be in accordance with requirements given in [1.1.2] and [1.1.3].

1.1.5 *Effective span of stiffeners supported by struts*

The arrangement of stiffeners supported by struts is not allowed for ships over 120 m in length. The span, l of stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as $0.7l_2$.

In case where two struts are fitted at 1/3 and 2/3 length between primary supporting members, the span, l of stiffeners is to be taken as $0.7l_2$.

l_1 and l_2 are the spans defined in Figure 7 and Figure 8.

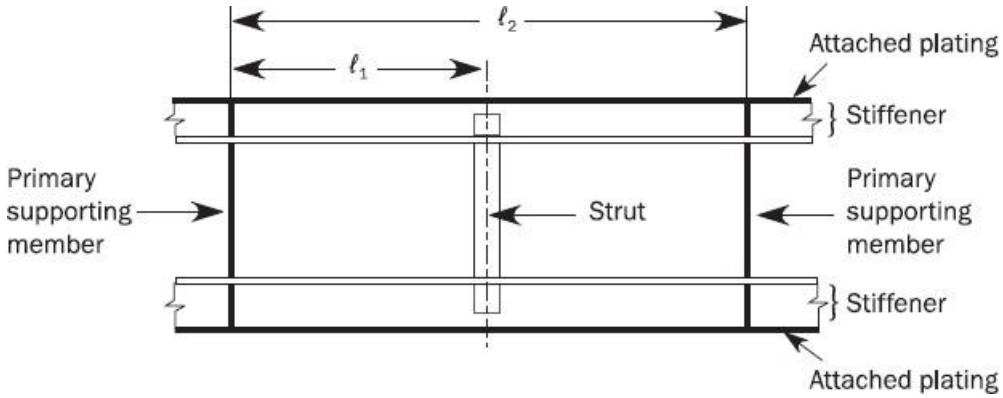


Figure 7 Span of stiffeners with one strut

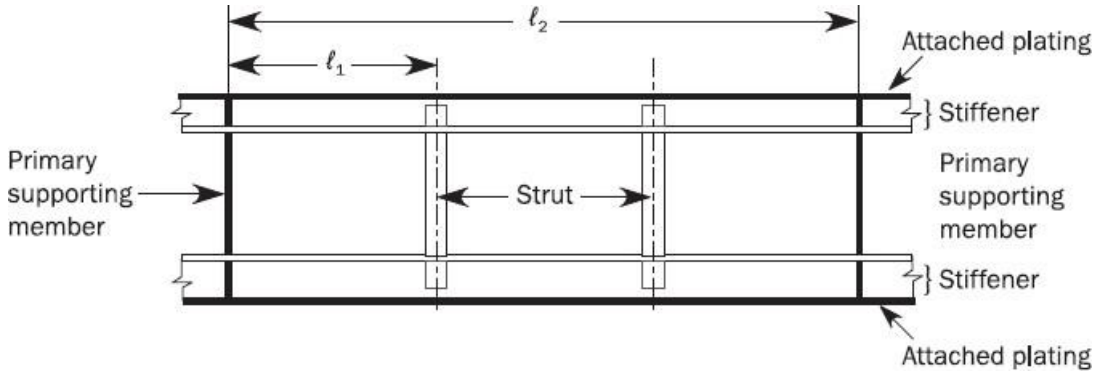
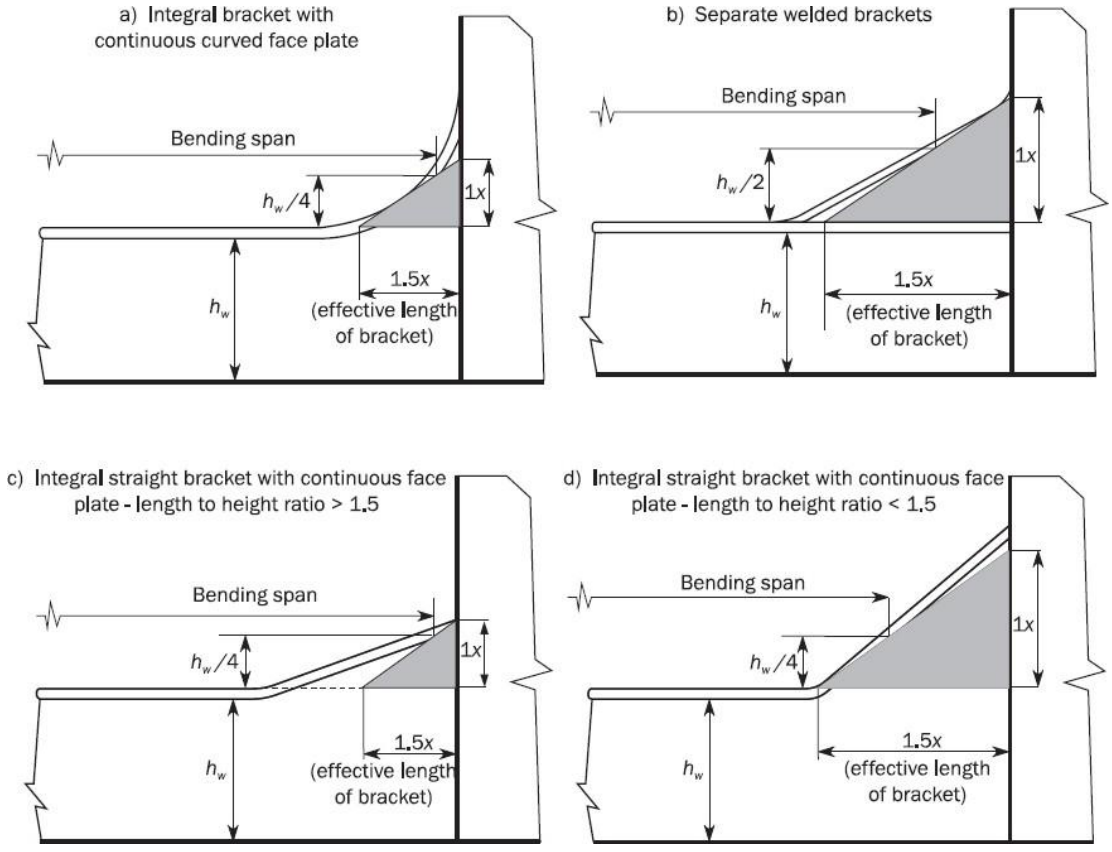


Figure 8 Span of stiffeners with two struts



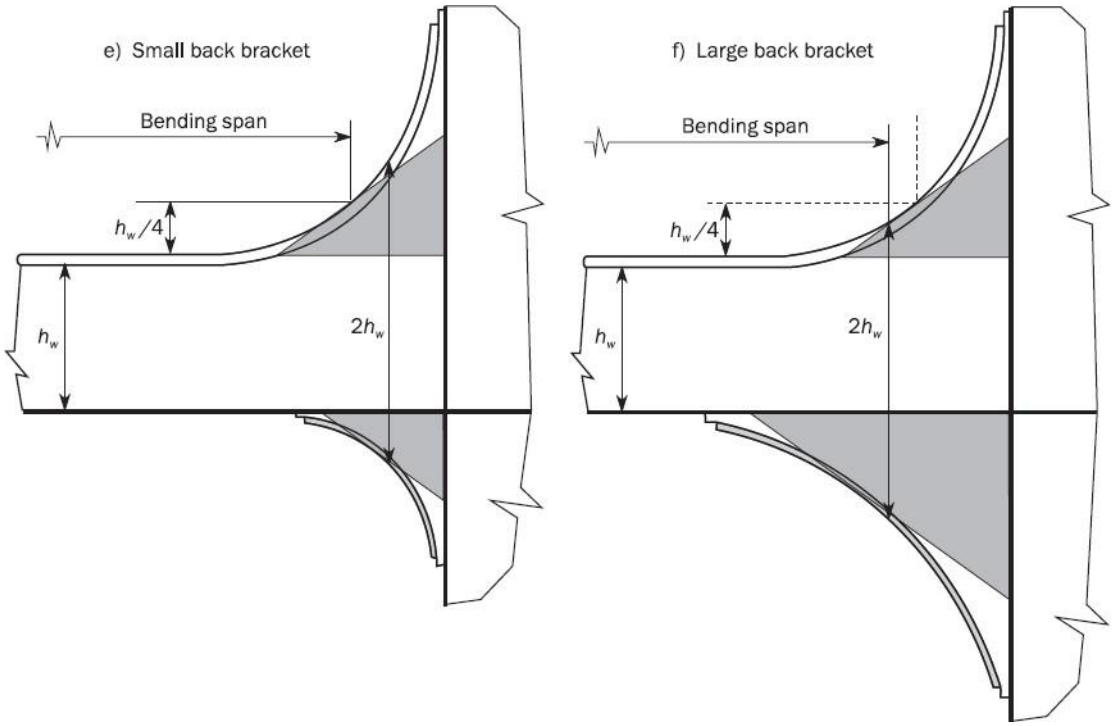
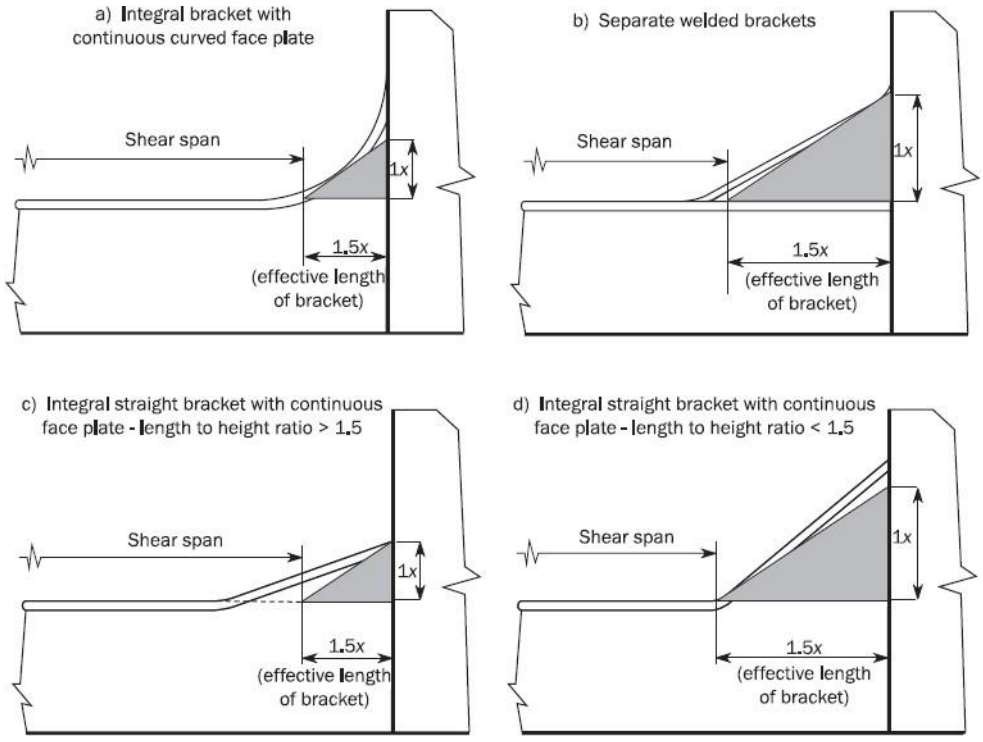


Figure 9 Effective bending span of primary supporting member



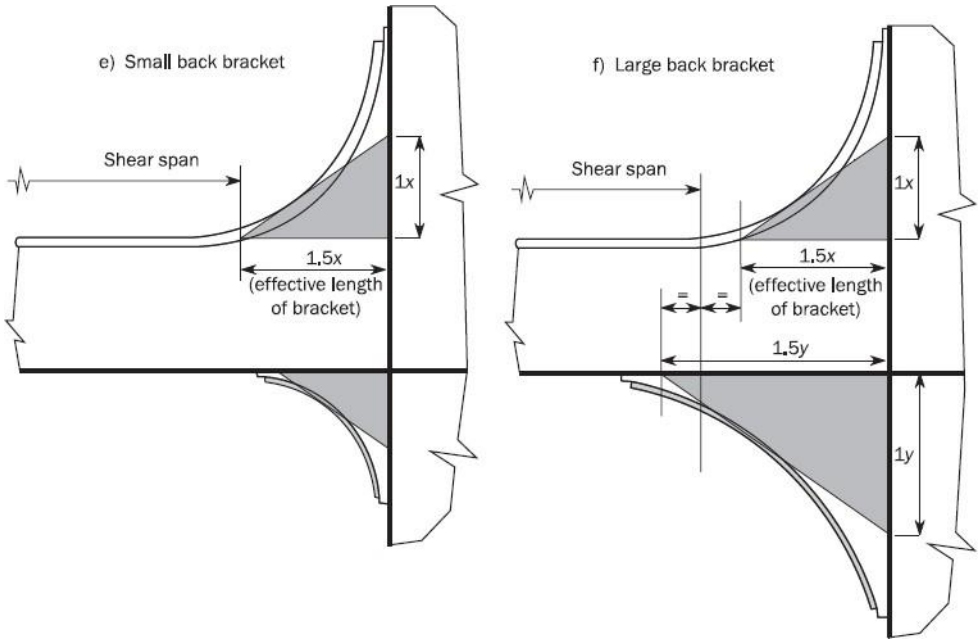


Figure 10 Effective shear span of primary supporting member

1.1.6 Effective bending span of primary supporting members

The effective bending span, l_{bdg}, in m, of a primary supporting member without end bracket is to be taken as the length of the member between supports.

The effective bending span, l_{bdg}, of a primary supporting member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.
The effective bending span l_{bdg}, in m, of a primary supporting member with end brackets is taken between points where the depth of the bracket is equal to half the web height of the primary supporting member as shown in item (b) of Figure 9. The effective bracket used to define these span points is to be taken as given in [1.1.8].

In case of brackets where the face plate of the member is continuous along the face of the bracket, as shown in items (a), (c) and (d) of Figure 9, the effective bending span l_{bdg}, in m, is taken between points where the depth of the bracket is equal to one quarter the web height of the primary supporting member. The effective bracket used to define these span points is to be taken as given in [1.1.8].

For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; otherwise the span point is to be taken to the fitted bracket.

For curved brackets, for span positions above the tangent point between fitted bracket and effective bracket, the span point is to be taken to the fitted bracket; otherwise, the span point is to be taken to the effective bracket.

For arrangements where the primary supporting member face plate is carried on to the bracket and backing brackets are fitted; the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary supporting member. Arrangements with small and large backing brackets are shown in items (e) and (f) of Figure 9.

For arrangements where the height of the primary supporting member is maintained and the face plate width is increased towards the support; the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

1.1.7 *Effective shear span of primary supporting members*

The effective shear span of the primary supporting member may be reduced compared to effective bending span, and taken between the toes of the effective brackets supporting the member, where the toes of effective brackets are as shown in Figure 10. The effective bracket used to define the toe point is given in [1.1.8].

For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in item (f) of Figure 10.

1.1.8 *Effective bracket definition*

The effective bracket is defined as the maximum size of right angled triangular bracket with a length to height ratio of 1.5 that fits inside the fitted bracket. See Figure 9 for examples.

1.2 *Spacing and load supporting breadth*

1.2.1 Stiffeners

Stiffeners spacing, *s*, in mm, for the calculation of the effective attached plating of stiffeners is to be taken as the mean spacing between stiffeners and taken equal to, see Figure 11.

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4: Spacings between stiffeners at ends, in mm.

In general, the loading breadth supported by stiffener is to be taken equal to *s*.

1.2.2 *Primary supporting member*

Primary supporting member spacing, *S*, for the calculation of the effective attached plating of primary supporting members is to be taken as the mean spacing between adjacent primary supporting members, and taken equal to, see Figure 11.

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4: Spacings between primary supporting members at ends.

In general, the loading breadth supported by a primary supporting member is to be taken equal to *S*.

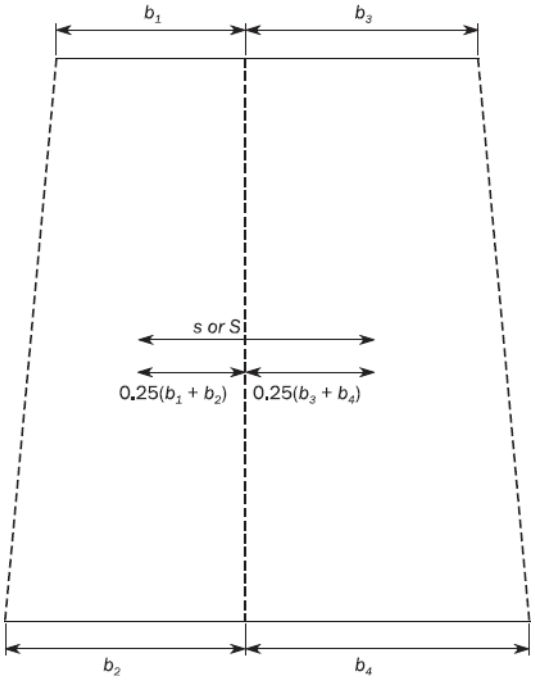


Figure 11 Spacing of plating

1.2.3 *Spacing of curved plating*

For curved plating, the stiffener spacing, *s* or the primary supporting member spacing, *S* is to be measured on the mean chord between members.

1.3 *Effective breadth*

1.3.1 Stiffeners

The effective breadth, b_{eff}, in mm, of the attached plating to be considered in the actual net section modulus for the yielding check of stiffeners is to be obtained from the following formulae:

- Where the plating extends on both sides of the stiffener:
  $b_{eff} = 200l$, or
  $b_{eff} = s$
  Whichever is lesser.
- Where the plating extends on one side of the stiffener (i.e. stiffeners bounding openings):
  $b_{eff} = 100l$, or
  $b_{eff} = 0.5\ s$
  Whichever is lesser.

However, where the attached plate net thickness is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

The effective breadth, b_{eff}, in mm, of the attached plating to be considered for the buckling check of stiffeners is given in Ch8, Sec 5, [2.3.5].

1.3.2 *Primary supporting members*

The effective breadth of attached plating, b_{eff}, in m, for calculating the section modulus and/or moment of inertia of a primary supporting member is to be taken as:

$$b_{eff} = S \min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{l_{bdg}}{S\sqrt{3}}\right)^{1.6}}};1.0\right] \quad \text{for } \frac{l_{bdg}}{S\sqrt{3}} \geq 1$$

$$b_{eff} = 0.407\frac{l_{bdg}}{\sqrt{3}} \quad \text{for } \frac{l_{bdg}}{S\sqrt{3}} < 1$$

1.3.3 *Effective area of curved face plate and attached plating of primary supporting members*

The effective net area given in a) and b) is only applicable to curved face plates and curved attached plating of primary supporting members. This is not applicable for the area of web stiffeners parallel to the face plate.

The effective net area is applicable to primary supporting members for the following calculations:

- Actual net section modulus used for comparison with the scantling requirements in Ch6.
- Actual effective net area of curved face plates, modelled by beam elements, used in Ch7.

a) The effective net area, $A_{eff\text{-}n50}$, in mm^2, is to be taken as:

$A_{eff\text{-}n50} = C_f\, t_{f\text{-}n50}\, b_f$

where:

C_f : Flange efficiency coefficient is to be obtained from the following formula but not to be greater than 1.0:

$$C_f = C_{f1}\frac{1.285}{\beta k_1} \quad \text{for symmetrical face plate}$$

$$C_f = 0.18 + \frac{0.08}{\beta^2}$$ for unsymmetrical face plate

$$C_f = C_{f1}\frac{1.285}{\beta k_1}$$ for attached plating of box girders

C_{f1} : Coefficient taken equal to:

- For symmetrical face plates,

$$C_{f1} = \frac{(\sinh k_1\beta \cosh k_1\beta + \sin k_1\beta \cos k_1\beta)}{(\cos hk_1\beta)^2 + (\cos k_1\beta)^2}$$

- For attached plating of box girders with two webs,

$$C_{f1} = \frac{0.78\ (\sinh \beta + \sin \beta)(\cosh \beta - \cos \beta)}{\sinh^2 \beta + \sin^2 \beta}$$

- For attached plating of box girders with multiple webs,

$$C_{f1} = \frac{1.56\ (\cosh \beta - \cos \beta)}{\sinh \beta + \sin \beta}$$

k_1 : Coefficient calculated as:

$k_1 = 1.4 + 1.25(1.4 - \beta)^3$ for $\beta < 1.4$

$k_1 = 1.4$ for $\beta \geq 1.4$

β : Coefficient calculated as:

$$\beta = \frac{1.285\ b_1}{\sqrt{r_f\ t_{f-n50}}}$$, in rad.

b_1 : Breadth, in mm, to be taken equal to:

- For symmetrical face plates, $b_1 = 0.5\ (b_f - t_w\text{-}n_{50})$
- For unsymmetrical face plates, $b_1 = b_f$
- For attached plating of box girders, $b_1 = s_w - t_w\text{-}n_{50}$

s_w : Spacing of supporting webs for box girders, in mm.

$t_{f\text{-}n50}$: Net flange thickness, in mm. For calculation of C_f and β of unsymmetrical face plates, $t_{f\text{-}n50}$ is not to be taken greater than $t_{w\text{-}n50}$.

$t_{w\text{-}n50}$: Net web plate thickness, in mm.

r_f : Radius of curved face plate or attached plating, in mm, see Figure 12 at mid thickness.

b_f : Breadth of face plate or attached plating, in mm, see Figure 12.

b) The effective net area, in mm^2, of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, is given by:

$$A_{eff-n50} = \left(\frac{3r_f t_{f-n50} + C_f s_r^2}{3r_f t_{f-n50} + s_r^2} \right) t_{f-n50} b_f$$

where:

s_r : Spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in mm, see Figure 12.

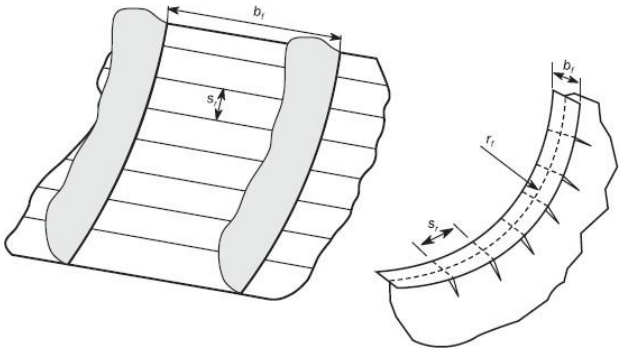


Figure 12 Curved shell panel and face plate

1.4 *Geometrical properties of stiffeners and primary supporting members*

1.4.1 Stiffener profile with a bulb section

The properties of bulb profile sections are to be determined by direct calculations.

Where direct calculation of properties is not possible, a bulb section may be taken equivalent to a built-up section. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where:

h'_w, t'_w : Net height and thickness of a bulb section, in mm, as shown in Figure 13.

α : Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \leq 120$$

$$\alpha = 1.0 \quad \text{for } h'_w > 120$$

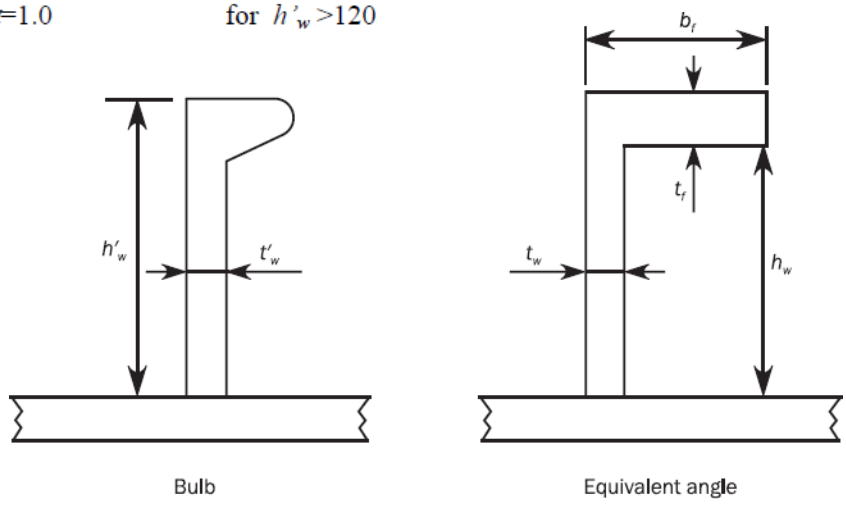


Figure 13 Dimensions of stiffeners

1.4.2 Net elastic shear area of stiffeners

The net elastic shear area, A_{shr}, in cm^2, of stiffeners is to be taken as:

$$A_{sh} = d_{shr}\, t_w 10^{-2}$$

d_{shr} : Effective shear depth of stiffener, in mm, as defined in [1.4.3].

t_w : Net web thickness of the stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

1.4.3 *Effective shear depth of stiffeners*

The effective shear depth of stiffeners, d_{shr}, in mm, is to be taken as:

$$d_{shr} = (h_{stf} - 0.5t_{c\text{-}stf} + t_p + 0.5t_{c\text{-}pl})\sin\varphi_w$$

where:

h_{stf}: Height of stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

t_p : Net thickness of the stiffener attached plating, in mm, as defined in Ch 3, Sec 2, Figure 2.

t_{c_stf} :Corrosion addition, in mm, of considered stiffener as given in Ch 3, Sec 3.

t_{c_pl} : Corrosion addition, in mm, of attached plate of the stiffener considered as given in Ch 3, Sec 3.

1.4.4 *Elastic net section modulus and net moment of inertia of stiffeners*

The elastic net section modulus, Z , in cm^3 and the net moment of inertia, I, in cm^4 of stiffeners, is to be taken as:

$Z = Z_{stf} \sin \varphi_w$

$I = I_{st} \sin^2 \varphi_w$

where:

Z_{stf} : Net section modulus of the stiffener, in cm^3, considered perpendicular to its attached plate, i.e. with φ_w = 90 deg.

I_{st}: Net moment of inertia of the stiffener, in cm^4, considered perpendicular to its attached plate, i.e. with φ_w = 90 deg.



Figure 14 Angle between stiffener web and attached plating

1.4.5 Effective net plastic shear area of stiffeners

The net plastic shear area, $A_{shr\text{-}pl}$, of stiffeners, in cm^2, which is used for assessment against impact loads is to be taken as:

$A_{shr\text{-}pl} = A_{shr}$

where:

A_{shr} : Net elastic shear area, in cm^2, as defined in [1.4.2].

1.4.6 *Effective net plastic section modulus of stiffeners*

The effective net plastic section modulus, Z_{pl}, of stiffeners, in cm^3, which is used for assessment against impact loads, is to be taken as:

$$Z_{pl} = \frac{f_w \, h_w{}^2 \, t_w}{2000} + \frac{(2\gamma - 1) A_f h_{f-ctr}}{1000} \quad \text{for } 75^\circ \leqslant \varphi_w \leqslant 105^\circ$$

$$Z_{pl} = \frac{f_w \, h_w{}^2 \, t_w \sin\phi_w}{2000} + \frac{(2\gamma - 1) A_f \left(h_{f-ctr} \sin\phi_w - b_{f-ctr} \left| \cos\phi_w \right| \right)}{1000} \quad \text{for } \varphi_w < 75^\circ \text{ or } \varphi_w > 105^\circ$$

where:

f_w : Web shear stress factor, taken equal to:

- For flanged profile cross sections with n = 1 or 2, f_w = 0.75.
- For flanged profile cross sections with n = 0, f_w = 1.0.
- For flat bar stiffeners, f_w = 1.0.

n : Number of plastic hinges at end supports of each member, taken equal to: 0, 1 or 2.

A plastic hinge at end support may be considered where:

- The stiffener is continuous at the support.
- The stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners.
- The stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener).
- The stiffener is attached to a bracket effective in bending. The bracket is assumed to be effective in bending when it is attached to another stiffener (not a buckling stiffener).

h_w: Depth of stiffener web, in mm, taken equal to:

- For T, L (rolled and built-up) profiles and flat bar, as defined in Ch 3, Sec 2, Figure 2

- For L2 profile as defined in Ch 3, Sec 2, Figure 3,
- For bulb profiles, to be taken as defined in [1.4.1].

γ : Coefficient equal to:

$$\gamma = \frac{1+\sqrt{3+12\beta}}{4}$$

β : Coefficient equal to:

- $\beta = \frac{t_w^2 f_b l_{shr}^{\ 2}}{80 b_f^2 t_f h_{f-ctr}} 10^6 + \frac{t_w}{2b_f}$ for L profiles without a mid-span tripping bracket,but not to be taken greater than 0.5.
- β= 0.5 for other cases.

A_f :Net cross sectional area of flange, in mm^2:

- A_f = 0 for flat bar stiffeners.
- $A_f = b_f t_f$ for other stiffeners.

$b_{f\text{-}ctr}$: Distance from mid thickness of stiffener web to the centre of the flange area:

- $b_{f\text{-}ctr} = 0.5\ (b_f - t_w)$ for rolled angle profiles and bulb profiles.
- $b_{f\text{-}ctr}$ = 0 for T profiles.

$h_{f\text{-}ctr}$: Height of stiffener measured to the mid thickness of the flange:

- $h_{f\text{-}ctr} = h_w + 0.5t_f$ for profiles with flange of rectangular shape and for bulb profiles.

f_b : Coefficient taken equal to:

- f_b = 0.8 for flanges continuous through the primary supporting member, with end bracket(s).
- f_b= 0.7 for flanges sniped at the primary supporting member or terminated at the support without aligned structure on the other side of the support, and with end bracket(s).
- f_b = 1.0 for other stiffeners.

t_f : Net flange thickness, in mm.

- t_f = 0 for flat bar stiffeners.
- For bulb profiles t_f is defined in [1.4.1].

1.4.7 *Primary supporting member web not perpendicular to attached plating*

Where the primary supporting member web is not perpendicular to the attached plating, the actual net shear area, in cm^2, and the actual net section modulus, in cm3, can be obtained from the following formulae:

- Actual net shear area:
  $A_{sh-n50} = A_{sh-0-n50}\sin\varphi_w$
- Actual net section modulus:
  $Z_{n50} = Z_{perp-n50}\sin\varphi_w$

where:

$A_{sh-0-n50}$: Actual net shear area, in cm^2, of the primary supporting member assumed to be perpendicular to the attached plating, to be taken equal to:

$$A_{sh-0-n50} = \left(h_{eff} + t_{f-n50} + t_{p-n50}\right) t_{w-n50}\, 10^{-2}$$

$Z_{perp-n50}$: Actual section modulus, in cm^3, with its attached plating of the primary supporting member assumed to be perpendicular to the attached plating.

1.4.8 *Shear area of primary supporting members with web openings*

The effective web height, h_{eff}, in mm, to be considered for calculating the effective net shear area, $A_{sh\text{-}n50}$ is to be taken as the lesser of:

$h_{eff} = h_w$

$h_{eff} = h_{w3} + h_{w4}$

$h_{eff} = h_{w1} + h_{w2} + h_{w4}$

where:

h_w : Web height of primary supporting member, in mm.

h_{w1}, h_{w2}, h_{w3}, h_{w4} : Dimensions as shown in Figure 16.

Where an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_{eff} is to be taken as the smaller of the net height and the net distance through the opening. See Figure 16.

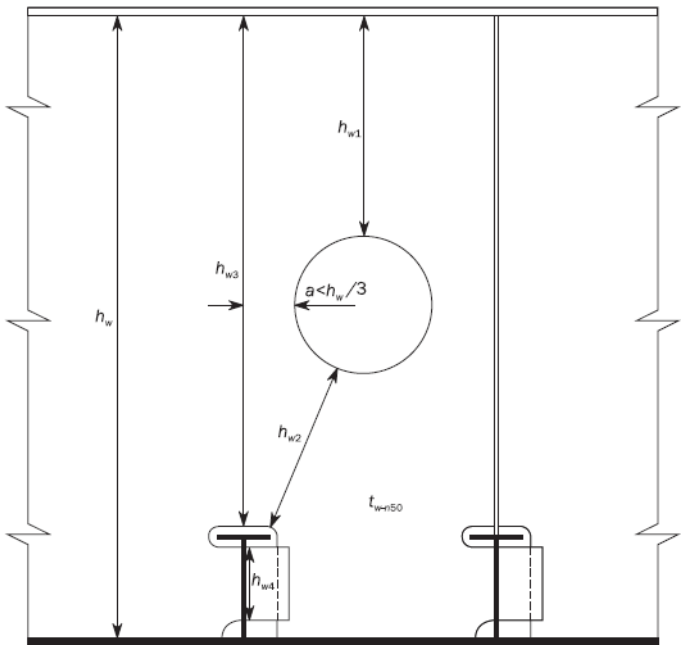


Figure 15 Effective shear area in way of web openings

1.4.9 Stiffener flange width

In case the stiffener flange thickness requirement in Ch 8, Sec 2, [3.1.1] b) is not fulfilled, the effective free flange outstand, used in strength assessment including the calculation of actual net section modulus, is to be taken as $b_{f\text{-}out\text{-}max}$ defined in Ch 8, Sec 2, [3.1.1].

2 PLATES

2.1 Idealisation of EPP

2.1.1 EPP

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 16.

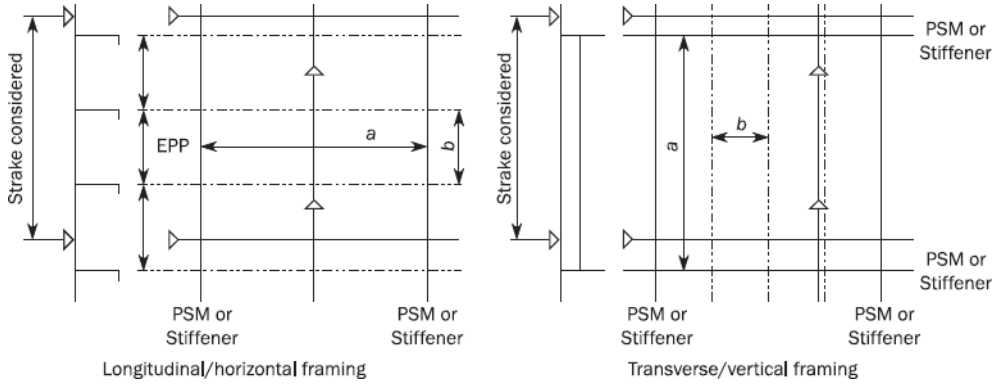


Figure 16 Elementary Plate Panel (EPP) definition

2.1.2 Strake required thickness

The required thickness of a plate strake is to be taken as the greatest value required for each EPP within that strake. The requirements given in Table 1 are to be applied for the selection of strakes to be considered as shown in Figure 17.

The maximum corrosion addition within a strake is to be applied according to Ch3, Sec 3, [1.2.4].

Strake considered in a given EPP *Table 1*

	$a/b>2$	$a/b\leq 2$
$a_1>b/2$	All strakes (St1, St2, St3, St4)	All strakes (St1, St2, St3, St4)

	$a/b>2$	$a/b\leq 2$
$a_1 \leq b / 2$	Strakes St2 and St4	All strakes (St1, St2, St3, St4)

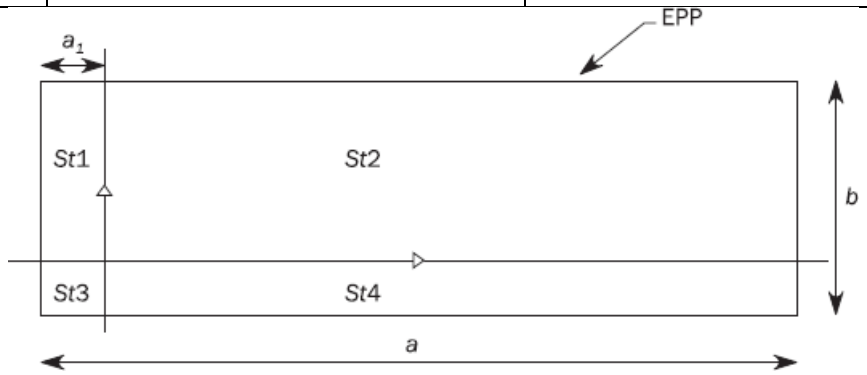


Figure 17 Strake considered in a given EPP

where:

a_1 : Distance, in mm, measured inside the considered strake in the direction of the long edge of the EPP, between the strake boundary weld seam and the EPP edge.

2.1.3

For direct strength assessment, the EPP is idealised with the mesh arrangement in the finite element model.

2.2 *Load calculation point*

2.2.1 Yielding

For the yielding check, the local pressure and hull girder stress, used for the calculation of the local scantling requirements are to be taken at the Load Calculation Point (LCP) having coordinates *x*, *y* and *z* as defined in Table 2.

LCP coordinates for yielding *Table 2*

LCP coordinates	General (1)		Horizontal plating		Vertical transverse structure and transverse stool plating	
	Longitudinal framing (Figure 18)	Transverse framing (Figure 19)	Longitudinal framing	Transverse framing	Horizontal framing (Figure 20)	Vertical framing (Figure 21)
x coordinate	Mid-length of the EPP		Mid-length of the EPP		Corresponding to y and z values	
y coordinate	Corresponding to *x* and *z* coordinates		Outboard y value of the EPP		Outboard y value of the EPP, taken at z level(2)	
z coordinate	Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake	Corresponding to x and y values		Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake

(1) All structures other than horizontal platings or vertical transverse structures.
(2) For transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

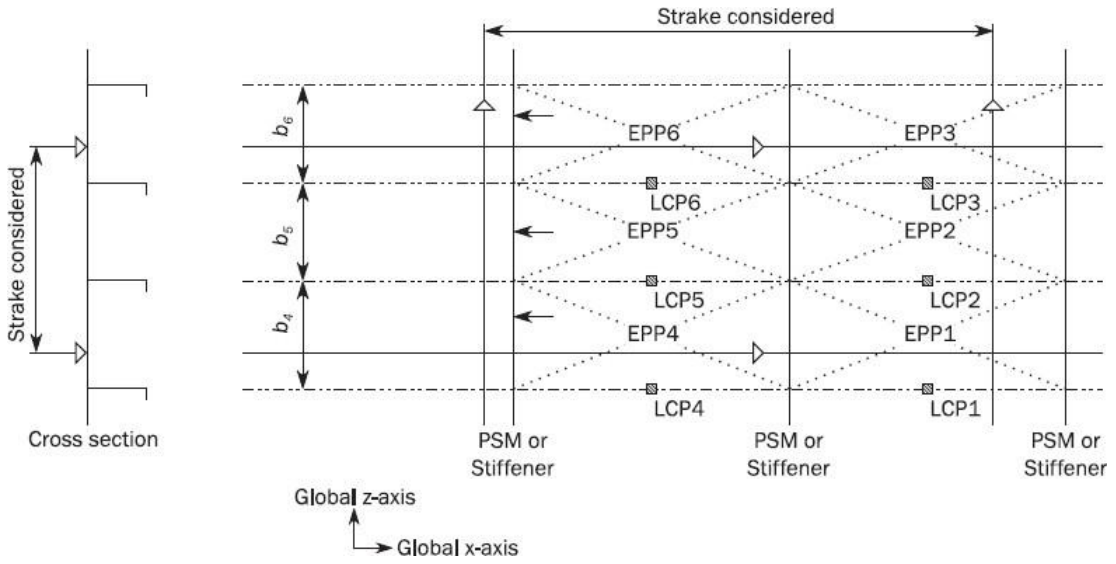


Figure 18 Load calculation point (LCP) for longitudinal framing

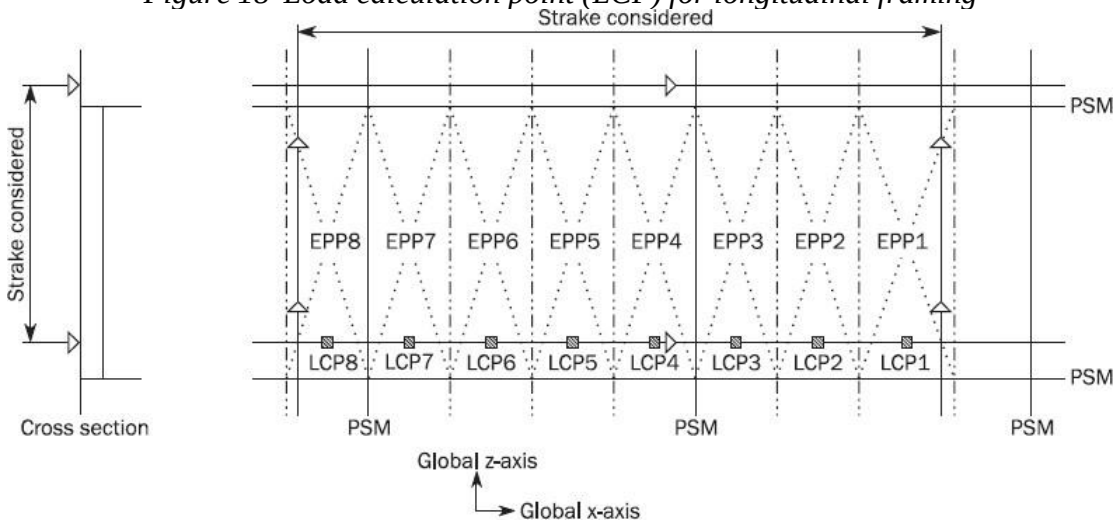


Figure 19 Load calculation point for transverse framing

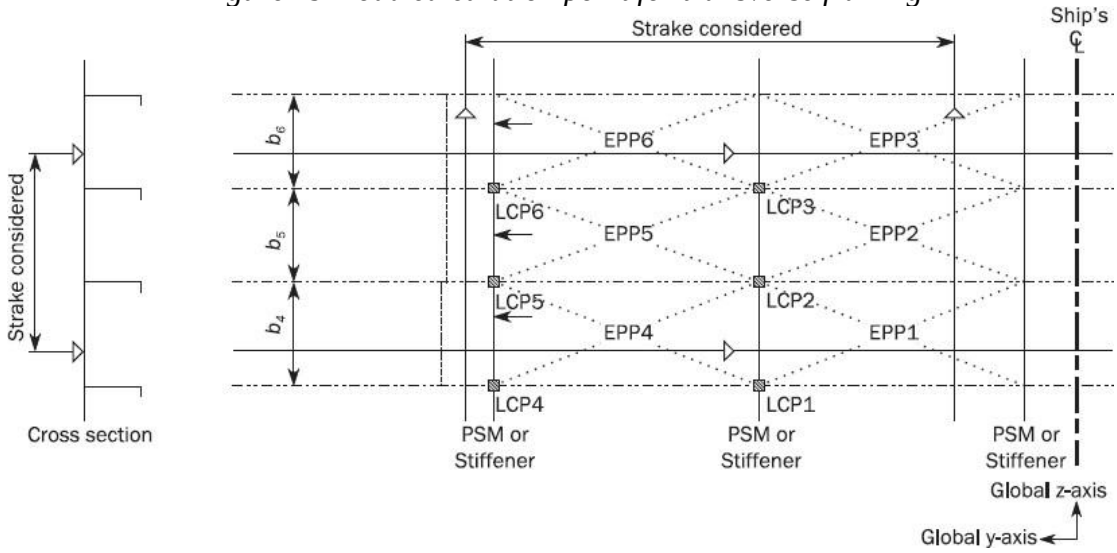


Figure 20 Load calculation point for horizontal framing on transverse vertical structure

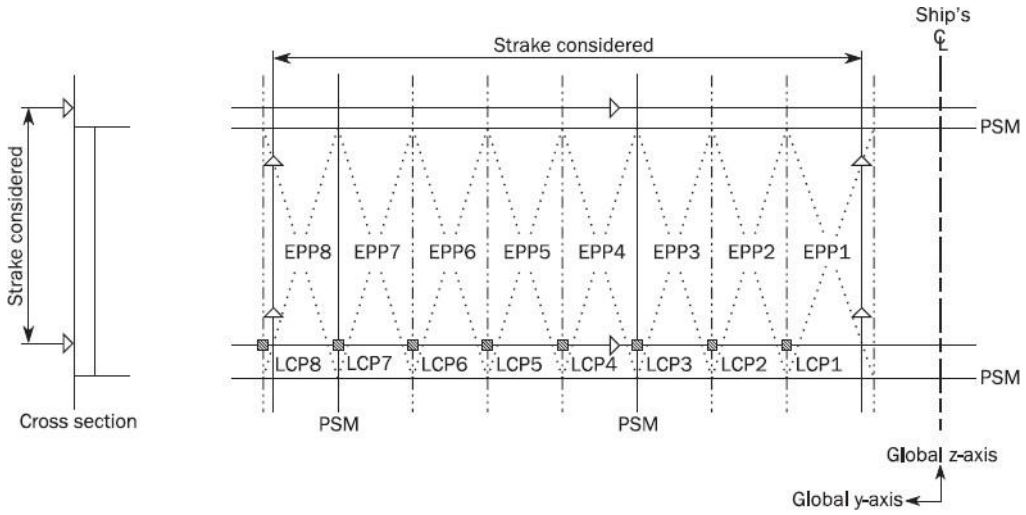


Figure 21 Load calculation point for vertical framing on transverse vertical structure

2.2.2 Buckling

For the prescriptive buckling check of the EPP according to Ch 8, Sec 3, the LCP for the pressure and for the hull girder stresses are defined in Table 3.

For the FE buckling check, Ch 8, Sec 4 is applicable.

LCP coordinates for plate buckling *Table 3*

LCP coordinates	LCP for pressure	LCP for hull girder stresses (Figure 22)		
		Bending stresses(1)		Shear stresses
		Non horizontal plate	Horizontal plate	
x coordinate	Same coordinates as LCP for yielding See Table 2	Mid-length of the EPP		
y coordinate		Corresponding to *x* and *z* values	Outboard and inboard ends of the EPP (points A1 and A2)	Mid-point of EPP (point B)
z coordinate		Both upper and lower ends of the EPP (points A1 and A2)	Corresponding to *x* and *y* values	
(1) The bending stress for curved plate panel is the mean value of the stresses calculated at points A1 and A2.				

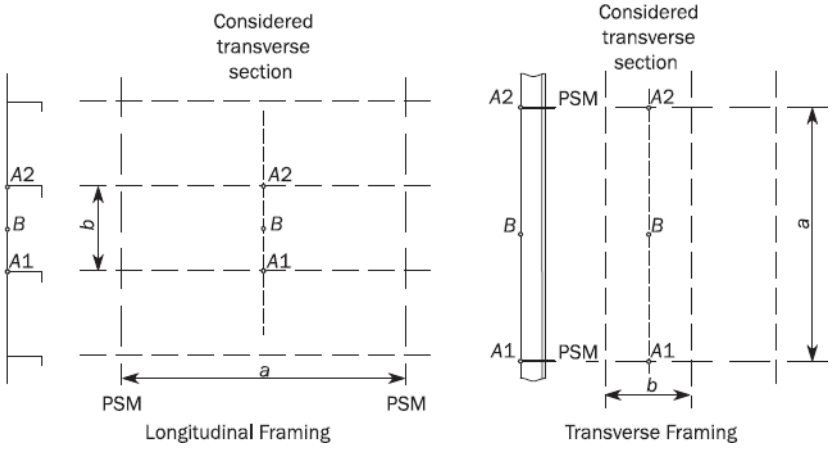


Figure 22 LCP for plate buckling – hull girder stresses

3 STIFFENERS

3.1 Reference point

3.1.1

The requirements of section modulus for stiffeners relate to the reference point giving the minimum section modulus. This reference point is generally located as shown in Figure 23 for typical profiles.

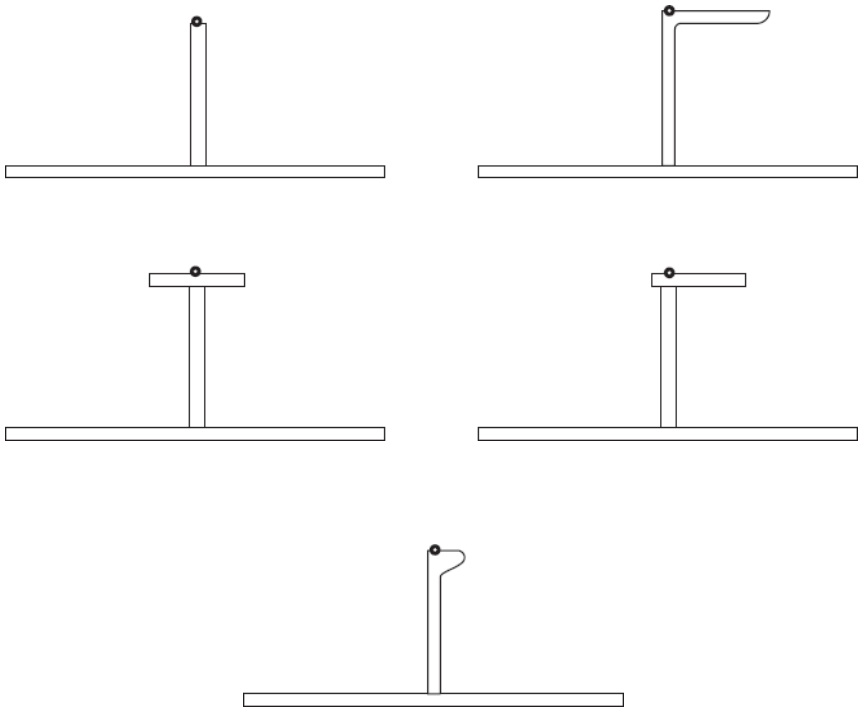


Figure 23 Reference point for calculation of section modulus and hull girder stress for local scantling assessment

3.2 Load calculation points

3.2.1 LCP for Pressure

The load calculation point for the pressure is located at:

- Middle of the full length, *l*, of the considered stiffener.
- The intersection point between the stiffener and its attached plate.

For stiffeners located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

3.2.2 *LCP for hull girder bending stress*

The load calculation point for the hull girder bending stresses is defined as follows:

- For prescriptive yielding verification according to Ch 6 and Ch 10, Sec 4:
  - At the middle of the full length, l, of the considered stiffener.
  - At the reference point given in Figure 23.
- For prescriptive buckling requirements according to Ch 8:
  - At the middle of the full length, *l*, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plate.

3.2.3 *Non-horizontal stiffeners*

The lateral pressure, *P* is to be calculated as the maximum between the value obtained at middle of the full length, *l*, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$ when the upper end of the vertical stiffener is below the lowest zero pressure level.

$P = \frac{l_1}{l}\frac{p_L}{2}$ when the upper end of the vertical stiffener is at or above the lowest zero pressure

level, see Figure24.

where:

l_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level.

P_U, P_L : Lateral pressures at the upper and lower end of the vertical stiffener span l, respectively.

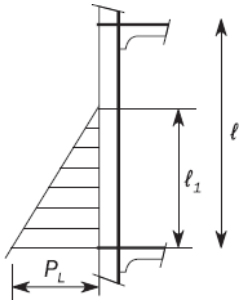


Figure 24 Definition of pressure for vertical

stiffeners 4 PRIMARY SUPPORTING MEMBERS

4.1 Load calculation point

4.1.1

The load calculation point is located at the middle of the full length, *S*, at the attachment point of the primary supporting member with its attached plate. However, for primary supporting members in the cargo hold region the requirements in Pt 2, Ch 1, Sec 4, [4], as applicable, for bulk carriers and Pt 2, Ch 2, Sec 3, [1] for oil tankers are to be followed.

For primary supporting members located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of load calculation point for the external dynamic pressure calculation.

Chapter 4 LOADS

Section 1 INTRODUCTION

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.
S : Static load case.
S+D: Static plus dynamic load case.

1 GENERAL
1.1 Application
1.1.1 Scope
This chapter provides the design load for strength and fatigue assessments.

The load combinations are to be derived for the design load scenarios specified in Ch4, Sec 7. This section uses the concept of design load scenarios to specify consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

1.1.2 *Equivalent Design Wave EDW*
The dynamic loads associated with each dynamic load case are based on the Equivalent Design Wave (EDW) concept. The EDW concept applies a consistent set of dynamic loads to the ship such that specified dominant load response is equivalent to the required long term response value.

1.1.3 *Probability level for strength and fatigue assessments*
In this chapter, the assessments are to be understood as follows:

- Strength assessment means the assessment for the strength criteria excluding fatigue, for the loads corresponding to the probability level of 10^{-8}, for the ballast water exchange, for harbour conditions and for flooded conditions.
- Fatigue assessment means the assessment for the fatigue criteria for the loads corresponding to the probability level of 10^{-2}.

1.1.4 *Dynamic load components*
All dynamic load components are to be concurrent values calculated for each dynamic load case.

1.1.5 *Loads for strength assessment*
The strength assessment is to be undertaken for all design load scenarios and the final assessment is to be made on the most onerous strength requirement.

Each design load scenario for strength assessment is composed of a Static (S) load case or a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered.
The static loads are defined in the following sections:

- Still water hull girder loads in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

The EDWs for the strength assessment and the dynamic load combination factors for global loads are listed in Ch4, Sec 2, [2].

The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

1.1.6 *Loads for fatigue assessment*

Each design load scenario for fatigue assessment is composed of a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered. The static loads are defined in the following sections:

- Still water hull girder loads in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

The EDWs for the fatigue assessment are listed in Ch4, Sec 2, [3]. The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch 4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

1.2 *Definitions*

1.2.1 Coordinate system

The coordinate system is defined in Ch 1, Sec 4, [3.6.1].

1.2.2 *Sign convention for ship motions*

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Figure 1, where:

- Positive surge is translation in the X-axis direction (positive forward).
- Positive sway is translation in the Y-axis direction (positive towards port side of ship).
- Positive heave is translation in the Z-axis direction (positive upwards).
- Positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and port up).
- Positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up).
- Positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to port and stern to starboard).

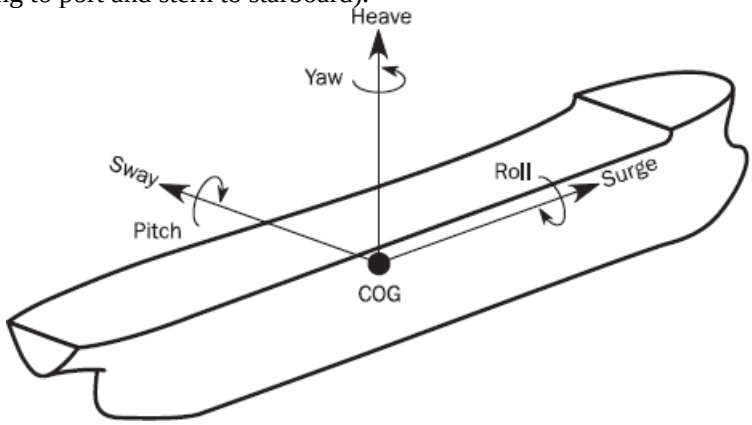


Figure 1 Definition of positive Motions

1.2.3 Sign convention for hull girder loads

The sign conventions of vertical bending moments, vertical shear forces, horizontal bending moments and torsional moments at any ship transverse section are as shown in Figure 2, namely:

- The vertical bending moments M_{sw} and M_{wv} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces Q_{sw}, Q_{wv} are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration.
- The horizontal bending moment M_{wh} is positive when it induces tensile stresses in the starboard side and negative when it induces tensile stresses in the port side.

- The torsional moment M_{wt} is positive in the case of resulting moment acting aft of the transverse section following negative rotation around the *X*-axis, and of resulting moment acting forward of the transverse section following positive rotation around the *X*-axis.

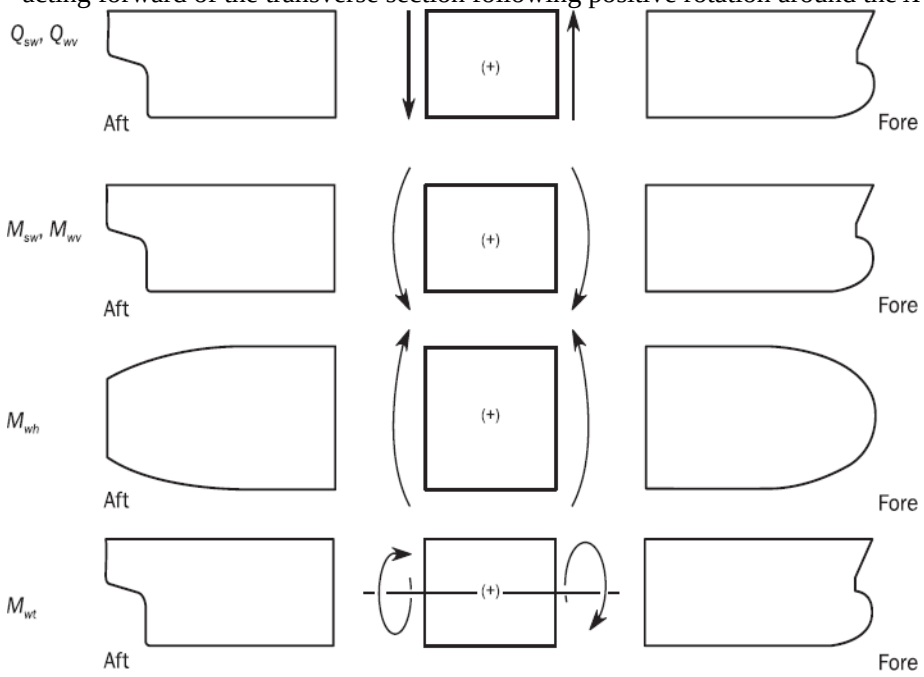


Figure 2 Sign conventions for shear forces Q_{sw}, Q_{wv} and bending moments M_{sw}, M_{wv}, M_{wh} **and M_{wt}**

Section 2 DYNAMIC LOAD CASES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_{surge}, $a_{pitch\text{-}x}$, a_{sway}, $a_{roll\text{-}y}$, a_{heave}, $a_{roll\text{-}z}$, $a_{pitch\text{-}z}$: Acceleration components, as defined in Ch 4, Sec 3.

f_{xL} : Ratio between X-coordinate of the load point and L, to be taken as:

$$f_{xL} = \frac{x}{L}$$, but not to be taken less than 0.0 or greater than 1.0.

f_T : Ratio between draught at a loading condition and scantling draught, as defined in Ch 4, Sec 3.

f_{lp} : Factor depending on longitudinal position along the ship, to be taken as:

$f_{lp} = 1.0$ for $x/L \leq 0.5$

$f_{lp} = -1.0$ for $0.5 < x/L$

$f_{lp\text{-}OST}$: Factor for the longitudinal distribution of the torsional moment for the OST load case, to be taken as:

$f_{lp\text{-}OST} = 5f_{xL}$ for $x/L < 0.2$

$f_{lp\text{-}OST} = 1.0$ for $0.2 \leq x/L < 0.4$

$f_{lp\text{-}OST} = -7.6f_{xL} + 4.04$ for $0.4 \leq x/L < 0.65$

$f_{lp\text{-}OST} = -0.9$ for $0.65 \leq x/L < 0.85$

$f_{lp\text{-}OST} = 6f_{xL} - 6$ for $0.85 \leq x/L$

$f_{lp\text{-}OSA}$: Factor for the longitudinal distribution of the torsional moment for the OSA load case, to be taken as:

$f_{lp\text{-}OSA} = -(0.2 + 0.3\, f_T)$ for $x/L < 0.4$

$f_{lp\text{-}OSA} = -(0.2 + 0.3\, f_T)(5.6 - 11.5\, f_{xL})$ for $0.4 \leq x/L < 0.6$

$f_{lp\text{-}OSA} = 1.3(0.2 + 0.3\, f_T)$ for $0.6 \leq x/L$

WS : Weather side, side of the ship exposed to the incoming waves.

LS : Lee side, sheltered side of the ship away from the incoming waves.

M_{WV} : Vertical wave bending moment, in kNm, defined in Ch 4, Sec 4.

Q_{WV} : Vertical wave shear force, in kN, defined in Ch 4, Sec 4.

M_{WH} : Horizontal wave bending moment, in kNm, defined in Ch 4, Sec 4.

M_{WT} : Torsional wave bending moment, in kNm, defined in Ch 4, Sec 4.

C_{WV} : Load combination factor to be applied to the vertical wave bending moment.

C_{QW} : Load combination factor to be applied to the vertical wave shear force.

C_{WH} : Load combination factor to be applied to the horizontal wave bending moment.

C_{WT} : Load combination factor to be applied to the wave torsional moment.

C_{XS} : Load combination factor to be applied to the surge acceleration.

C_{XP} : Load combination factor to be applied to the longitudinal acceleration due to pitch.

C_{XG} : Load combination factor to be applied to the longitudinal acceleration due to pitch motion.

C_{YS} : Load combination factor to be applied to the sway acceleration.

C_{YR} : Load combination factor to be applied to the transverse acceleration due to roll.

C_{YG} : Load combination factor to be applied to the transverse acceleration due to roll motion.

C_{ZH} : Load combination factor to be applied to the heave acceleration.

C_{ZR} : Load combination factor to be applied to the vertical acceleration due to roll.

C_{ZP} : Load combination factor to be applied to the vertical acceleration due to pitch.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

φ : Pitch angle, in deg, as defined in Ch 4, Sec 3, [2.1.2].

1 *GENERAL*

1.1 Definition of dynamic load cases

1.1.1

The following Equivalent Design Waves (EDW) are to be used to generate the dynamic load cases for structural assessment:

- HSM load cases:
  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave

bending moment amidships respectively.

- HSA load cases:
  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.
- FSM load cases:
  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- BSR load cases:
  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.
  BSR-1S and BSR-2S: beam Sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.
- BSP load cases:
  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.
  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.
- OST load cases:
  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25*L* from the AE with waves from the port side respectively.
  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25*L* from the AE with waves from the starboard side respectively.
- OSA load cases:
  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.
  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

Note 1: 1 and 2 denote the maximum or the minimum dominate load component for each EDW.
Note 2: P and S denote that the weather side is on port side and on starboard side respectively.
HSA and OSA load cases are not to be used for fatigue assessment.

1.2 *Application*

1.2.1

The dynamic load cases described in this section are to be used for determining the dynamic loads required by the design load scenarios described in Ch 4, Sec 7. These dynamic load cases are to be applied to the following structural assessments:

a) Strength assessment:
   - For plating, ordinary stiffeners and primary supporting members by prescriptive methods.
   - For the direct strength method (FE analysis) assessment of structural members.

b) Fatigue assessment:
   - For structural details covered by simplified stress analysis.
   - For structural details covered by FE stress analysis.

2 *DYNAMIC LOAD CASES FOR STRENGTH ASSESSMENT*

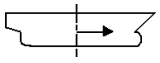
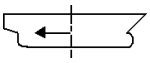
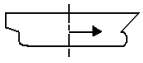
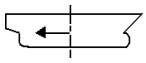
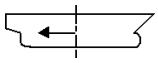
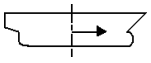
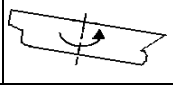
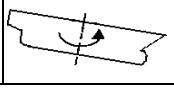
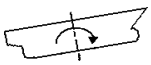
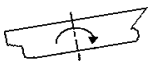
2.1 Description of dynamic load cases

2.1.1

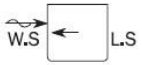
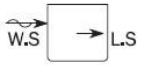
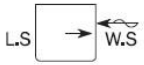
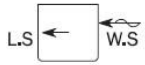
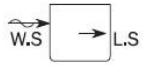
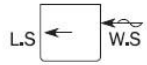
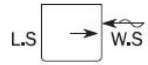
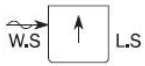
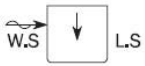
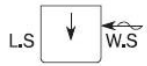
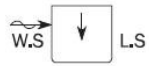
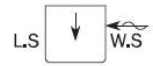
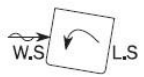
Table 1 to Table 3 describe the ship motions responses and the global loads corresponding to each dynamic load case to be considered for the strength assessment.

Ship responses for HSM, HSA and FSM load cases - Strength assessment
Table 1

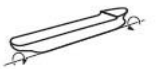
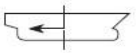
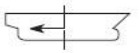
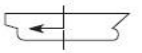
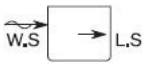
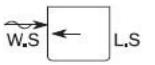
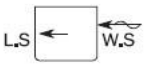
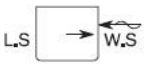
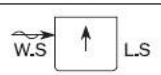
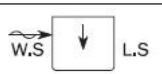
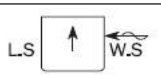
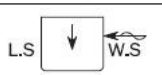
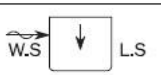
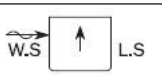
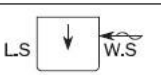
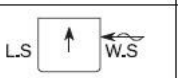
Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
EDW	HSM		HSA		FSM	
Heading	Head		Head		Following	
Effect	Max. bending moment		Max. vertical acceleration		Max. bending moment	

Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-	-	-
TM	-	-	-	-	-	-
Surge	To stern	To bow	To stern	To bow	To bow	To stern
a_{surge}						
Sway	-	-	-	-	-	-
a_{sway}	-	-	-	-	-	-
Heave	Down	Up	Down	Up	-	-
a_{heave}					-	-
Roll	-	-	-	-	-	-
a_{roll}	-	-	-	-	-	-
Pitch	Bow down	Bow up	Bow down	Bow up	Bow up	Bow down
a_{pitch}						

Ship responses for BSR and BSP load cases - Strength assessment **Table 2**

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	-	-	-	-	Bow down	Bow up	Bow down	Bow up
a_{pitch}	-	-	-	-				

Ship responses for OST and OSA load cases - Strength assessment **Table 3**

Load case	OST-1P	OST-2P	OST-1S	OST-2S	OSA-1P	OSA-2P	OSA-1S	OSA-2S
EDW	OST				OSA			
Heading	Oblique				Oblique			
Effect	Max. torsional moment				Max. pitch acceleration			
VWBM	Sagging	Hogging	Sagging	Hogging	Hogging	Sagging	Hogging	Sagging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM								
Surge	To bow	To stern	To bow	To stern	To bow	To stern	To bow	To stern
a_{surge}								
Sway	-	-	-	-	To portside	To starboard	To starboard	To portside
a_{sway}	-	-	-	-				
Heave	Down	Up	Down	Up	Up	Down	Up	Down
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down
a_{pitch}								

2.2 *Load combination factors 2.2.1*

The load combinations factors, LCFs for the global loads and inertia load components for strength assessment are defined in:

Table 4 : LCFs for HSM, HSA and FSM load cases.

Table 5 : LCFs for BSR and BSP load cases.

Table 6 : LCFs for OST and OSA load cases.

Load combination factors, LCFs for HSM, HSA and FSM load cases - Strength assessment

Table 4

Load component		LCF	HSM-1	HSM-2	HAS-1	HAS-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	-0.7	0.7	-0.4f_T-0.6	0.4f_T+0.6
	Q_{WV}	C_{QW}	-1.0f_{lp}	1.0f_{lp}	-0.6f_{lp}	0.6f_{lp}	-1.0f_{lp}	1.0f_{lp}
	M_{WH}	C_{WH}	0	0	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0.3-0.2f_T	0.2f_T-0.3	0.2	-0.2	0.2-0.4f_T	0.4f_T-0.2
	$a_{pitch-x}$	C_{XP}	-0.7	0.7	-0.4f_T -0.4	0.4f_T +0.4	0.15	-0.15
	$g$sinφ	C_{XG}	0.6	-0.6	0.4f_T+0.4	-0.4f_T-0.4	-0.2	0.2
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0	0	0
	$g$sinθ	C_{YG}	0	0	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	0.5f_T-0.15	0.15-0.5f_T	0.4f_T -0.1	0.1-0.4f_T	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.7	0.7	-0.4f_T-0.4	0.4f_T+0.4	0.15	-0.15

Load combination factors, LCFs for BSR and BSP load cases - Strength assessment

Table 5

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	0.1-0.2f_T	0.2f_T -0.1	0.1-0.2f_T	0.2f_T -0.1
	Q_{WV}	C_{QW}	(0.1-0.2f_T) f_{lp}	(0.2f_T -0.1) f_{lp}	(0.1-0.2f_T) f_{lp}	(0.2f_T -0.1) f_{lp}
	M_{WH}	C_{WH}	1.2- 1.1f_T	1.1f_T -1.2	1.1f_T -1.2	1.2-1.1 f_T
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	$g$sinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	0.2-0.2f_T	0.2f_T -0.2	0.2f_T -0.2	0.2-0.2f_T
	a_{roll-y}	C_{YR}	1	-1	-1	1
	$g$sinθ	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	0.7-0.4f_T	0.4f_T-0.7	0.7-0.4f_T	0.4f_T-0.7
	a_{roll-z}	C_{ZR}	1	-1	1	-1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	0.3-0.8f_T	0.8f_T-0.3	0.3-0.8f_T	0.8f_T-0.3
	Q_{WV}	C_{QW}	(0.3-0.8f_T) f_{lp}	(0.8f_T-0.3) f_{lp}	(0.3-0.8f_T) f_{lp}	(0.8f_T-0.3) f_{lp}
	M_{WH}	C_{WH}	0.7- 0.7f_T	0.7f_T -0.7	0.7f_T -0.7	0.7- 0.7f_T
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0.1-0.3f_T	0.3f_T -0.1	0.3f_T -0.1	0.1-0.3f_T
	gsinφ	C_{XG}	0.3f_T -0.1	0.1-0.3f_T	0.3f_T -0.1	0.1-0.3f_T
Transverse accelerations	a_{sway}	C_{YS}	-0.9	0.9	0.9	-0.9
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	$g$sinθ	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	0.1-0.3f_T	0.3f_T-0.1	0.1-0.3f_T	0.3f_T-0.1

Load combination factors, LCFs for OST and OSA load cases - Strength assessment

Table 6

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	-0.3-0.2f_T	0.3+0.2f_T	-0.3-0.2f_T	0.3+0.2f_T
	Q_{WV}	C_{QW}	(-0.35-2f_T)f_{lp}	(0.35+0.2f_T)f_{lp}	(-0.35-0.2f_T)f_{lp}	(0.35+0.2f_T)f_{lp}
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	-f_{lp-OST}	f_{lp-OST}	f_{lp-OST}	-f_{lp-OST}
Longitudinal accelerations	a_{surge}	C_{XS}	0.1f_T -0.15	0.15-0.1f_T	0.1f_T -0.15	0.15-0.1f_T
	$a_{pitch-x}$	C_{XP}	0.7-0.3f_T	0.3f_T -0.7	0.7-0.3f_T	0.3f_T -0.7
	$g$sinφ	C_{XG}	0.2f_T-0.45	0.45-0.2f_T	0.2f_T-0.45	0.45-0.2f_T
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0.4f_T-0.25	0.25-0.4f_T	0.25-0.4f_T	0.4f_T-0.25
	$g$sinθ	C_{YG}	0.1-0.2f_T	0.2f_T-0.1	0.2f_T-0.1	0.1-0.2f_T
Vertical accelerations	a_{heave}	C_{ZH}	0.2f_T-0.05	0.05-0.4f_T	0.2f_T-0.05	0.05-0.4f_T
	a_{roll-z}	C_{ZR}	0.4f_T-0.25	0.25-0.4f_T	0.25-0.4f_T	0.4f_T-0.25
	$a_{pitch-z}$	C_{ZP}	0.7-0.3f_T	0.3f_T-0.7	0.7-0.3f_T	0.3f_T-0.7

Load component		LCF	OSA-1P	OSA-2P	OSA-1S	OSA-2S
Hull girder loads	M_{WV}	C_{WV}	0.75-0.5f_T	-0.75+0.5f_T	0.75-0.5f_T	-0.75+0.5f_T
	Q_{WV}	C_{QW}	(0.6-0.4f_T) f_{lp}	(-0.6+0.4f_T) f_{lp}	(0.6-0.4f_T) f_{lp}	(-0.6+0.4f_T) f_{lp}
	M_{WH}	C_{WH}	0.55+0.2f_T	-0.55-0.2f_T	-0.55-0.2f_T	0.55+0.2f_T
	M_{WT}	C_{WT}	-f_{lp-OSA}	f_{lp-OSA}	f_{lp-OSA}	-f_{lp-OSA}
Longitudinal accelerations	a_{surge}	C_{XS}	0.1f_T -0.45	0.45-0.1f_T	0.1f_T -0.45	0.45-0.1f_T
	$a_{pitch-x}$	C_{XP}	1.0	-1.0	1.0	-1.0
	gsinφ	C_{XG}	-1.0	1.0	-1.0	1.0
Transverse	a_{sway}	C_{YS}	-0.2 -0.1f_T	0.2+0.1f_T	0.2+0.1f_T	-0.2 -0.1f_T

Load component		LCF	OSA-1P	OSA-2P	OSA-1S	OSA-2S
accelerations	$a_{roll\text{-}y}$	C_{YR}	0.3-0.2f_T	0.2f_T -0.3	0.2f_T -0.3	0.3-0.2f_T
	gsinθ	C_{YG}	0.1f_T-0.2	0.1-0.2f_T	0.2-0.1f_T	0.1f_T-0.2
Vertical accelerations	a_{heave}	C_{ZH}	-0.2f_T	0.2f_T	-0.2f_T	0.2f_T
	$a_{roll\text{-}z}$	C_{ZR}	0.3-0.2f_T	0.2f_T-0.3	0.2f_T-0.3	0.3-0.2f_T
	$a_{pitch\text{-}z}$	C_{ZP}	1.0	-1.0	1.0	-1.0

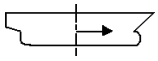
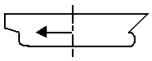
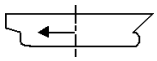
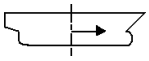
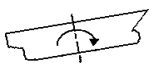
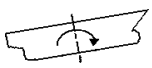
3 *DYNAMIC LOAD CASES FOR FATIGUE ASSESSMENT*

3.1 Description of dynamic load cases

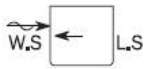
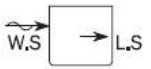
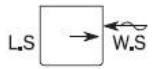
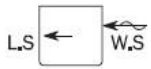
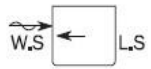
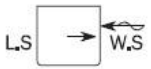
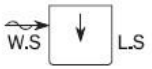
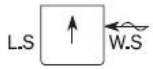
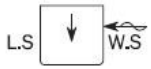
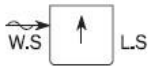
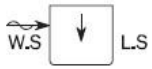
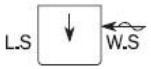
3.1.1

Table 7 to Table 9 define the ship motions responses and the global loads corresponding to each dynamic load case to be considered for fatigue assessment.

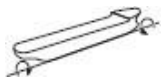
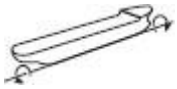
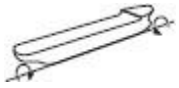
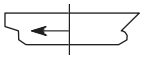
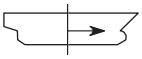
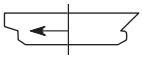
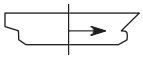
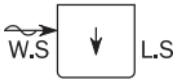
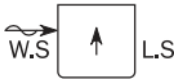
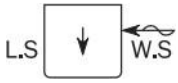
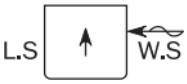
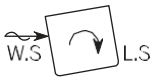
Ship responses for HSM and FSM load cases - Fatigue assessmentTable 7

Load case	HSM-1	HSM-2	FSM-1	FSM-2
EDW	HSM		FSM	
Heading	Head		Following	
Effect	Max. bending moment		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-
TM	-	-	-	-
Surge	To stern	To bow	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Down	Up	-	-
a_{heave}			-	-
Roll	-	-	-	-
a_{roll}	-	-	-	-
Pitch	Bow down	Bow up	Bow up	Bow down
a_{pitch}				

Ship responses for BSR and BSP load cases - Fatigue assessment **Table 8**

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	-	-	-	-	-	-	-	-
a_{pitch}	-	-	-	-	-	-	-	-

Ship responses for OST load cases - Fatigue assessment *Table 9*

Load case	OST-1P	OST-2P	OST-1S	OST-2S
EDW	OST			
Heading	Oblique			
Effect	Max. torsional moment			
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
TM				
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside down	Portside up	Starboard down	Starboard up
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				

3.2 Load combination factors

3.2.1

The load combinations factors, LCFs for the global loads and inertial load components for fatigue assessment are defined in:

Table 10: LCFs for HSM and FSM load cases. Table 11: LCFs for BSR and BSP load cases. Table 12: LCFs for OST load case.

Load combination factors, LCFs for HSM and FSM load cases - Fatigue assessment

Table 10

Load component		LCF	HSM-1	HSM-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	-0.75-0.2f_T	0.75+0.2f_T
	Q_{WV}	C_{QW}	-1.0f_{lp}	1.0f_{lp}	(-0.75-.2f_T)f_{lp}	(0.75+0.2f_T)f_{lp}
	M_{WH}	C_{WH}	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0.3-0.2f_T	0.2f_T-0.3	0.2-0.4f_T	0.4f_T-0.2
	$a_{pitch-x}$	C_{XP}	-0.9	0.9	0.1	-0.1

Load component		LCF	HSM-1	HSM-2	FSM-1	FSM-2
	gsinφ	C_{XG}	$0.4f_T$+0.4	-$0.4f_T$-0.4	-0.15	0.15
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	$g$sinθ	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.8f_T$-0.15	0.15-$0.8f_T$	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.9	0.9	0.1	-0.1

Load combination factors, LCFs for BSR and BSP load cases - Fatigue assessment

Table 11

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	0.1-$0.2f_T$	$0.2f_T$ -0.1	0.1-$0.2f_T$	$0.2f_T$ -0.1
	Q_{WV}	C_{QW}	(0.1-$0.2f_T$) f_{lp}	($0.2f_T$ -0.1) f_{lp}	(0.1-$0.2f_T$) f_{lp}	($0.2f_T$ -0.1) f_{lp}
	M_{WH}	C_{WH}	1.1- f_T	f_T -1.1	f_T -1.1	1.1- f_T
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	gsinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	0.2-$0.2f_T$	$0.2f_T$ -0.2	$0.2f_T$ -0.2	0.2-$0.2f_T$
	a_{roll-y}	C_{YR}	1	-1	-1	1
	$g$sinθ	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	0.7-$0.4f_T$	$0.4f_T$-0.7	0.7-$0.4f_T$	$0.4f_T$-0.7
	a_{roll-z}	C_{ZR}	1	-1	1	-1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	0.3-$0.8f_T$	$0.8f_T$-0.3	0.3-$0.8f_T$	$0.8f_T$-0.3
	Q_{WV}	C_{QW}	(0.3-$0.8f_T$) f_{lp}	($0.8f_T$-0.3) f_{lp}	(0.3-$0.8f_T$) f_{lp}	($0.8f_T$-0.3) f_{lp}
	M_{WH}	C_{WH}	0.6- $0.6f_T$	$0.6f_T$ -0.6	$0.6f_T$ -0.6	0.6- $0.6f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	gsinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	-0.95	0.95	0.95	-0.95
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	gsinθ	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load combination factors, LCFs for OST load cases Fatigue assessment
Table 12

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	-0.4	0.4	-0.4	0.4
	Q_{WV}	C_{QW}	$-0.4f_{lp}$	$0.4f_{lp}$	$-0.4f_{lp}$	$0.4f_{lp}$
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	$-f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$-f_{lp\text{-}OST}$
Longitudinal accelerations	a_{surge}	C_{XS}	$-0.25+0.2f_T$	$0.25-0.2f_T$	$-0.25+0.2f_T$	$0.25-0.2f_T$
	$a_{pitch\text{-}x}$	C_{XP}	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$
	gsinφ	C_{XG}	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	$a_{roll\text{-}y}$	C_{YR}	$-0.4+0.6f_T$	$0.4-0.6f_T$	$0.4-0.6f_T$	$-0.4+0.6f_T$
	gsinθ	C_{YG}	$0.2-0.3f_T$	$-0.2+0.3f_T$	$-0.2+0.3f_T$	$0.2-0.3f_T$
Vertical accelerations	a_{heave}	C_{ZH}	-0.05	0.05	-0.05	0.05
	$a_{roll\text{-}z}$	C_{ZR}	$-0.4+0.6f_T$	$0.4-0.6f_T$	$0.4-0.6f_T$	$-0.4+0.6f_T$
	$a_{pitch\text{-}z}$	C_{ZP}	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$

Section 3 SHIP MOTIONS AND ACCELERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_0 : Acceleration parameter, to be taken as:

$$a_0 = (1.58 - 0.47C_B)\left[\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right]$$

T_θ : Roll period, in s, as defined in [2.1.1].

θ : Roll angle, in deg, as defined in [2.1.1].

T_φ : Pitch period, in s, as defined in [2.1.2].

φ : Pitch angle, in deg, as defined in [2.1.2].

R : Vertical coordinate, in m, of the ship rotation centre, to be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR}, *and* C_{ZP}: Load combination factors, as defined in Ch 4, Sec 2.

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s2, as defined in [3.3.2].

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s2, as defined in [3.3.1].

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s2, as defined in [3.3.3].

$a_{pitch\text{-}z}$: Vertical acceleration due to pitch, in m/s2, as defined in [3.3.3].

f_T : Ratio between draught at a loading condition and scantling draught, to be taken as:

$$f_T = \frac{T_{LC}}{T_{SC}} \text{ but is not to be taken less than 0.5}$$

T_{LC} : Draught, in m, amidships for the considered load case

x, y, z : X, Y and Z coordinates, in m, of the considered point with respect to the coordinate system, as defined in Ch 4, Sec 1, [1.2.1].

f_{ps} : Coefficient for strength assessments which is dependant on the applicable design load scenario specified in Ch 4, Sec 7, and to be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario.

f_{ps} = 0.8 for the ballast water exchange design load scenario.

f_{ps} = 0.8 for the accidental flooded design load scenario at sea.

f_{ps} = 0.4 for the harbour/sheltered water design load scenario.

f_{fa} : Fatigue coefficient to be taken as:

f_{fa} = 0.9

1 GENERAL

1.1 Definition

1.1.1

The ship motions and accelerations are assumed to be sinusoidal. The motion values defined by the formulae in this section are single amplitudes, i.e. half of the 'crest to trough' height.

2 SHIP MOTIONS AND ACCELERATIONS

2.1 Ship motions

2.1.1 Roll motion

The roll period T_θ, in s, to be taken as:

$$T_\theta = \frac{2.3\pi k_r}{\sqrt{gGM}}$$

The roll angle θ, in deg, to be taken as:

$$\theta = \frac{9000(1.25 - 0.025T_\theta) f_p f_{BK}}{(B + 75)\pi}$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}(0.23\text{-}4f_T B\times 10^{-4})$ for fatigue assessment.

f_{BK} : To be taken as:

$f_{BK} = 1.2$ for ships without bilge keel.

$f_{BK} = 1.0$ for ships with bilge keel.

k_r : Roll radius of gyration, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

GM : Metacentric height, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

k_r and GM values for oil tankers **Table 1**

Loading condition (1) (2)	T_{LC}	k_r	GM
Full load condition	T_{SC}	0.35B	0.12B
Optional conditions that have a draught greater than $0.9T_{SC}$	Actual draught but $\geq 0.9T_{SC}$	0.35B	0.12B
Partial load condition	$\leq 0.6T_{SC}$	0.40B	0.24B
Ballast condition	T_{BAL}	0.45B	0.33B

(1) For optional loading conditions or gale/emergency ballast conditions with draught between $0.6T_{SC}$ and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation between the optional condition at $0.9T_{SC}$ and the partial load condition at $0.6T_{SC}$ based on the actual draught.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

k_r and GM values for bulk carriers **Table 2**

Loading condition (1) (2) (4)		Application	T_{LC}	k_r	GM
Full load condition	Homogeneous loading	All bulk carriers	T_{SC}	0.35B	0.12B
	Alternate heavy cargo	BC-A		0.40B	0.20B
	Alternate light cargo	BC-A		0.35B	0.12B
	Homogeneous heavy cargo	BC-B, BC-A		0.42B	0.25B
Steel coil loading (3)		All bulk carriers designated for the carriage of steel products		0.42B	0.25B
Heavy ballast condition		All bulk carriers	T_{BAL-H}	0.40B	0.25B
Normal ballast condition		All bulk carriers	T_{BAL}	0.45B	0.33B

(1) For Multi-port (MP) loading conditions with draught greater than or equal to $0.9T_{SC}$, the values of kr and GM, unless provided in the loading manual, are to be taken as those from the most appropriate full load condition. For Multi-port (MP) loading conditions with draught between T_{BAL-H} and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation, based on the draught, between the heavy ballast condition and the most appropriate full load condition.
For Multi-port (MP) loading conditions with a draught below T_{BAL-H}, the values of kr and GM for the heavy ballast condition are to be used.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

(3) When steel coil loading condition is provided by the designer according to Ch 1, Sec 2, [3.6] in the loading manual, this condition is to be assessed with draught, kr and GM values given in this table.

(4) Block Loading conditions are to be assessed with draught, k_r and GM values given in this table for Homogeneous heavy cargo loading condition.

2.1.2 Pitch motion

The pitch period T_φ, in s, is to be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\lambda_\varphi}{g}}$$

where:
$\lambda_\varphi = 0.6(1+f_T)L$
The pitch angle φ, in deg, is to be taken as:

$$\varphi = 1350 f_p L^{-0.94} \left\{ 1.0 + \left(\frac{2.57}{\sqrt{gL}} \right)^{1.2} \right\}$$

where:
f_p : Coefficient to be taken as:
$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[(0.27-0.02f_T)-(13-5f_T)\, L\times10^{-5}]$ for fatigue assessment

2.2 *Ship accelerations at the centre of gravity*

2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2, is to be taken as:
$a_{surge} = 0.2 f_p a_0 g$
where:
f_p : Coefficient to be taken as:
$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[0.27-(15+4f_T)\, L\times10^{-5}]$ for fatigue assessment.

2.2.2 *Sway acceleration*

The transverse acceleration due to sway, in m/s^2, is to be taken as:
$a_{sway} = 0.3 f_p a_0 g$
where:
f_p ： Coefficient to be taken as:
$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[0.24-(6-2f_T)\, B\times10^{-4}]$ for fatigue assessment.

2.2.3 *Heave acceleration*

The vertical acceleration due to heave, in m/s^2, is to be taken as:
$a_{heave} = f_p a_0 g$
where:
f_p : Coefficient to be taken as:
$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[(0.27+0.02f_T)\, -17L\times10^{-5}]$ for fatigue assessment.

2.2.4 *Roll acceleration*

The roll acceleration, a_{roll}, in rad/s^2, is to be taken as:

$$a_{roll} = f_p \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta} \right)^2$$

where:

θ : Roll angle using *fp* equal to 1.0.
f_p : Coefficient to be taken as:
$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[0.23-4f_T\, B\times10^{-4}]$ for fatigue assessment.

2.2.5 *Pitch acceleration*

The pitch acceleration, *apitch*, in rad/s2, is to be taken as:

$$a_{pitch} = f_p \theta \left(\frac{3.1}{\sqrt{gL}} + 1.0 \right) \varphi \frac{\pi}{180} \left(\frac{2\pi}{T_\varphi} \right)^2$$

where:

φ : Pitch angle using *fp* equal to 1.0.
f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[0.28-(5+6f_T)\,L\times10^{-5}]$ for fatigue assessment.

3 ACCELERATIONS AT ANY POSITION

3.1 General

3.1.1

The accelerations used to derive the inertial loads at any position are defined with respect to the ship fixed coordinate system. Hence the acceleration values defined in [3.2] and [3.3] include the gravitational acceleration components due to the instantaneous roll and pitch angles.

3.1.2

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2].

3.1.3

The envelope accelerations as defined in [3.3] are provided for advisory purposes and may be used for other design purpose when the maximum design acceleration values are required, for example, crane foundations, machinery foundations, etc.

3.2 *Accelerations for dynamic load cases*

3.2.1 General

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2.2] to [3.2.4].

3.2.2 *Longitudinal acceleration*

The longitudinal acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_X = -C_{XG}g\sin\varphi + C_{XS}a_{surge} + C_{XP}a_{pitch}(z-R)$

3.2.3 *Transverse acceleration*

The transverse acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_Y = -C_{YG}g\sin\theta + C_{YS}a_{sway} - C_{YR}a_{roll}\,(z-R)$

3.2.4 *Vertical acceleration*

The vertical acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_Z = -C_{ZH}\,a_{heave} + C_{ZR}a_{roll}y - C_{ZP}a_{pitch}\,(x-0.45L)$

3.3 *Envelope accelerations*

3.3.1 Longitudinal acceleration

The envelope longitudinal acceleration, $a_{x\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{x-env} = 0.7\sqrt{a_{surge}^2 + \left[\frac{L}{325}(g\sin\varphi + a_{pitch-x})\right]^2}$$

where:

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s^2

$a_{pitch\text{-}x} = a_{pitch}\,(z-R)$

3.3.2 *Transverse acceleration*

The envelope transverse acceleration, $a_{y\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{y-env} = \sqrt{a_{sway}^2 + (g\sin\theta + a_{roll-y})^2}$$

where:

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s^2.

$a_{roll\text{-}y} = a_{roll}\,(z-R)$

3.3.3 *Vertical acceleration*

The envelope vertical acceleration, $a_{z\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{z-env} = \sqrt{a_{heave}^2 + \left[\left(0.3 + \frac{L}{325}\right) a_{pitch-z}\right]^2 + (1.2 a_{roll-z})^2}$$

where:

$a_{picth\text{-}z}$: Vertical acceleration due to pitch, in m/s^2.

$a_{pitch\text{-}z} = a_{pitch}\,(x\text{-}0.45L)$

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s^2.

$a_{roll\text{-}z} = a_{roll} y$

Section 4 HULL GIRDER LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

C_w : Wave coefficient, to be taken as:

$$C_w = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5} \quad \text{for } 90\text{m} \leqslant L \leqslant 300\text{m}$$

$$C_w = 10.75 \quad \text{for } 300\text{m} < L \leqslant 350\text{m}$$

$$C_w = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5} \quad \text{for } 350\text{m} < L \leqslant 500\text{m}$$

f_β : Heading correction factor, to be taken as:

- For strength assessment:

  f_β =1.05 for HSM and FSM load cases for the extreme sea loads design load scenario.

  f_β =0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.

  f_β =1.0 for HSA, OST and OSA load cases for the extreme sea loads design load scenario.

  f_β =1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

- For fatigue assessment:

  f_β= 1.0.

f_{ps} : Coefficient, as defined in Ch 4, Sec 3.

BSR, *BSP*, *HSM*, *HSA*, *FSM*, *OST*, *OSA*: Dynamic load cases, as defined in Ch 4, Sec 2.

1 APPLICATION

1.1 General

1.1.1

The hull girder loads for the static (S) design load scenarios is to be taken as the still water loads defined in [2].

1.1.2

The total hull girder loads for the static plus dynamic (S+D) design load scenarios are to be derived for each dynamic load case and are to be taken as the sum of the still water loads defined in [2] and the dynamic loads defined in [3.5].

2 VERTICAL STILL WATER HULL GIRDER LOADS

2.1 General

2.1.1 Seagoing and harbour/sheltered water conditions

The designer is to provide the permissible still water bending moment and shear force for seagoing and harbour/sheltered water operations.

The permissible still water hull girder loads are to be given at each transverse bulkhead in the cargo hold region, at the middle of cargo compartments, at the collision bulkhead, at the engine room forward bulkhead and at the mid-point between the forward and aft engine room bulkheads. The permissible hull girder bending moments and shear forces at any other position may be obtained by linear interpolation.

Note1: It is recommended that, for initial design, the permissible hull girder hogging and sagging still water bending moments are at least 5% above the maximum still water bending moment from loading conditions in the loading manual, and the permissible hull girder shear forces are at least 10% above the maximum still water shear force from loading condition in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.2 *Flooded condition*

The designer is to provide the envelope of permissible still water bending moment and shear force in flooded condition.

2.1.3 *Still water loads for the fatigue assessment*

The still water bending moment and shear force values and distribution to be used for the fatigue assessment are to be taken as the most typical values applicable for the loading conditions that the ship will operate in for most of its life. Typically, these conditions will be the normal ballast condition and full homogeneously loaded condition for double hull oil tankers. For bulk carriers, these will be the normal ballast condition, heavy ballast condition, full homogeneously loaded condition and full alternate loaded condition; note the latter is only applicable to BC-A bulk carriers. The definition of loading conditions to use is specified in Ch9.

2.2 *Vertical still water bending moment*

2.2.1 Minimum still water bending moment

The minimum still water bending moment, $M_{sw\text{-}h\text{-}min}$ and $M_{sw\text{-}s\text{-}min}$, in kNm, in hogging and sagging condition, respectively is to be taken as:

Hogging conditions:

$$M_{sw\text{-}h\text{-}min}=f_{sw}(171C_wL^2B(C_B+0.7)10^{-3}-M_{wv\text{-}h\text{-}mid})$$

Sagging conditions:

$$M_{sw\text{-}s\text{-}min}= - 0.85f_{sw}(171C_wL^2B(C_B+0.7)10^{-3}+M_{wv\text{-}s\text{-}mid})$$

where:

$M_{wv\text{-}h\text{-}mid}$: Vertical wave bending moment for strength assessment in hogging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

$M_{wv\text{-}s\text{-}mid}$: Vertical wave bending moment for strength assessment in sagging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

f_{sw} : Distribution factor along the ship length. To be taken as, see Figure 1:

$f_{sw} = 0.0$ for $x \leq 0$

$f_{sw} = 0.15$ at $x = 0.1\ L$

$f_{sw} = 1.0$ for $0.3\ L \leq x \leq 0.7\ L$

$f_{sw} = 0.15$ at $x = 0.9\ L$

$f_{sw} = 0.0$ for $x \geq L$

Intermediate values of f_{sw} are to be obtained by linear interpolation.

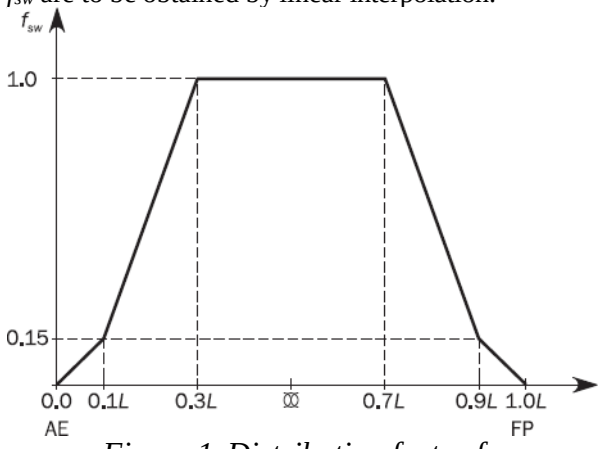


Figure 1 Distribution factor f_{sw}

2.2.2 Permissible vertical still water bending moment in seagoing condition

The permissible vertical still water bending moments, $M_{sw\text{-}h}$ and $M_{sw\text{-}s}$ in seagoing condition at any longitudinal position are to envelop:

- The most severe still water bending moments calculated, in hogging and sagging conditions, respectively, for the seagoing loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the seagoing loading conditions defined in the loading manual.
- The minimum still water bending moment defined in [2.2.1]

2.2.3 *Permissible vertical still water bending moment in harbour/sheltered water and tank testing condition*

The permissible vertical still water bending moments in the harbour/sheltered water and tank testing condition $M_{sw\text{-}p\text{-}h}$ and $M_{sw\text{-}p\text{-}s}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the harbour/sheltered water loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2].
- The minimum still water bending moment defined in [2.2.1] increased by 25%.

2.2.4 *Permissible vertical still water bending moment in flooded condition at sea*

The permissible vertical still water bending moments in flooded condition $M_{sw\text{-}f}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the intact and flooded seagoing loading conditions defined in Ch 4, Sec 8. Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.
- The most severe still water bending moments for the intact and flooded seagoing loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2] increased by 10%.

2.3 *Vertical still water shear force*

2.3.1 Minimum still water shear force in seagoing conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, $Q_{sw\text{-}min}$ in kN, in way of transverse bulkheads between cargo tanks in the seagoing condition is to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm \max \begin{cases} 0.225\rho g B_{local} l_{tk} T_{SC} \\ 0.5\rho g[0.98(V_{CT} + 2V_{ST}) - 0.7 B_{local} l_{tk} T_{SC}] \end{cases}$$

and is to be taken as the maximum value of $Qsw\text{-}min$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:
$Q_{sw\text{-}min} = \pm 0.4\rho g B_{local} l_{tk} T_{SC}$
and is to be taken as maximum value of $Qsw\text{-}min$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

where:

B_{local} : Local breadth, in m, at T_{SC} at the middle length of the tank under consideration.

l_{tk} : Length of cargo tank under consideration, in m, taken at the forward or aft side of the transverse bulkhead under consideration, in m.

V_{CT} : Volume of centre cargo tank, in m_3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

V_{ST} : Volume of side cargo tank, in m^3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

2.3.2 Minimum still water shear force in harbour/sheltered water conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, $Q_{sw\text{-}p\text{-}min}$ in kN in the harbour/sheltered water condition in way of transverse bulkheads between cargo tanks are to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm \max \begin{cases} 0.275\rho g B_{local} l_{tk} T_{SC} \\ 0.5\rho g[0.98(V_{CT} + 2V_{ST}) - 0.6 B_{local} l_{tk} T_{SC}] \end{cases}$$

and is to be taken as the maximum value of $Q_{sw\text{-}p\text{-}min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:
$Q_{sw\text{-}p\text{-}min} = \pm 0.45\rho g B_{local} l_{tk} T_{SC}$

and is to be taken as maximum value of $Q_{sw\text{-}p\text{-}min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

2.3.3 *Permissible still water shear force in seagoing condition*

The permissible vertical still water shear forces, Q_{sw} for oil tankers and bulk carriers, in seagoing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- For oil tankers, the minimum still water shear forces for seagoing conditions defined in [2.3.1].

2.3.4 *Permissible still water shear force in harbour/sheltered water and tank testing condition*

The permissible vertical still water shear forces, *Qsw-p* for oil tankers and bulk carriers, in the harbour/sheltered water and tank testing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible vertical still water shear force defined in [2.3.3].
- For oil tankers, the minimum still water shear forced for harbour/sheltered water conditions defined in [2.3.2].

The following value may be used as guidance at preliminary design stage:

$Q_{sw\text{-}p} = Q_{sw} + 0.6Q_{wv}$

where:

Q_{sw} : Permissible still water shear force Q_{sw}, as defined in [2.3.3].

Q_{wv} : Vertical wave shear force for strength assessment $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$, as defined in [3.2.1] using f_p equal to 1.0.

2.3.5 *Permissible still water shear force in flooded condition at sea*

The permissible vertical still water shear forces, *Qsw-f* for oil tankers and bulk carriers, in flooded condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the flooded seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier. Loading conditions encountered during ballast water exchange need not be considered for the flooded condition.
- The most severe still water shear forces for the flooded seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible still water shear force is defined in [2.3.3].

3 *DYNAMIC HULL GIRDER LOADS*

3.1 Vertical wave bending moment

3.1.1

The vertical wave bending moments at any longitudinal position, in kNm, are to be taken as:

Hogging condition:

$M_{wv\text{-}h} = 0.19 f_{nl\text{-}vh} f_m f_p C_w L^2 B C_B$

Sagging condition:

$M_{wv\text{-}s} = -0.19 f_{nl\text{-}vs} f_m f_p C_w L^2 B C_B$

where:

$f_{nl\text{-}vh}$: Coefficient considering nonlinear effects applied to hogging, to be taken as:

$f_{nl\text{-}vh}$ =1.0 for strength and fatigue assessment.

$f_{nl\text{-}vs}$: Coefficient considering nonlinear effects applied to sagging, to be taken as:

$$f_{nl-s} = 0.58\frac{(C_B + 0.7)}{C_B}, \text{ for strength assessment.}$$

$f_{nl\text{-}s}$ = 1.0, for fatigue assessment.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$, for strength assessment.

$f_p = 0.9[0.27-(6+4f_T)L\times10^{-5}]$, for fatigue assessment.

f_m : Distribution factor for vertical wave bending moment along the ship's length, to be taken as:

$f_m = 0.0$ for $x \le 0$

$f_m = 1.0$ for $0.4\,L \le x \le 0.65\,L$ f_m

$= 0.0$ for $x \ge L$

Intermediate values of *fm* are to be obtained by linear interpolation (see Figure 2).

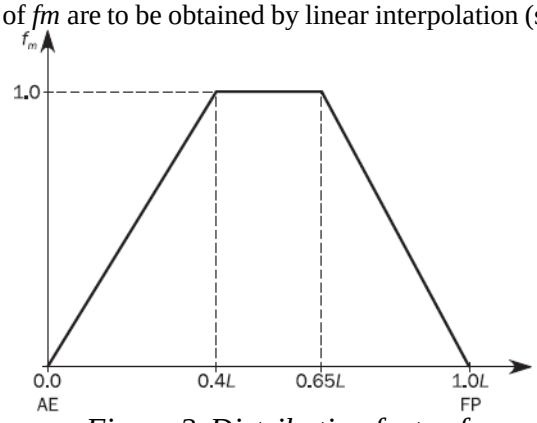


Figure 2 Distribution factor f_m

3.2 Vertical wave shear force

3.2.1

The vertical wave shear forces at any longitudinal position, in kN, are to be taken as:

$Q_{wv\text{-}pos}=0.52f_{q\text{-}pos}f_pC_wLBC_B$

$Q_{wv\text{-}neg}=-0.52f_{q\text{-}neg}f_pC_wLBC_B$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$,for strength assessment.

$f_p = 0.9[0.27-(17-8f_T)L\times10^{-5}]$, for fatigue assessment.

$f_{q\text{-}pos}$: Distribution factor along the ship length for positive wave shear force, to be taken as:

$f_{q\text{-}pos}$ = 0.0 for $x \le 0$

$f_{q\text{-}pos}$ = 0.92 f_{nl-vh} for 0.2 $L \le$ x $\le$ 0.3 L $f_{q\text{-}pos}$ = 0.7 for 0.4 $L \le x \le$ 0.6 L $f_{q\text{-}pos}$ = 1.0$f_{nl\text{-}vs}$ for 0.7 $L \le x \le$ 0.85 L $f_{q\text{-}pos}$ = 0.0 for $x \ge L$

Intermediate values of $f_{q\text{-}pos}$ are to be obtained by linear interpolation (see Figure 3).

$f_{q\text{-}neg}$: Distribution factor along the ship length for negative wave shear force, to be taken as:

$f_{q\text{-}neg}$ = 0.0 for $x \le 0$

$f_{q\text{-}neg}$ = 0.92f_{nl-vs} for 0.2$L \le$ x $\le$ 0.3 L $f_{q\text{-}neg}$ = 0.7 for 0.4$L \le$ x $\le$ 0.6 L $f_{q\text{-}neg}$ = 1.0f_{nl-vh} for 0.7$L \le$ x $\le$ 0.85 L $f_{q\text{-}neg}$

= 0.0 for x $\ge$ L

Intermediate values of $f_{q\text{-}neg}$ are to be obtained by linear interpolation, see Figure 4.

$f_{nl\text{-}vh}$, $f_{nl\text{-}vs}$: Coefficient considering nonlinear effects defined in [3.1.1].

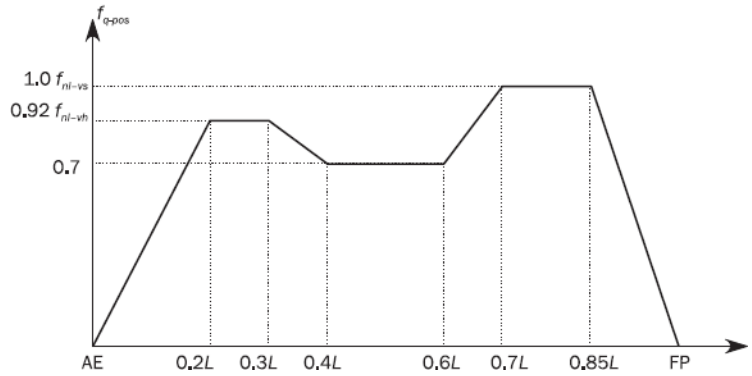


Figure 3 Distribution factor of positive vertical shear force $f_{q\text{-}pos}$

3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any longitudinal position, in kNm, is to be taken as:

$$M_{wh} = f_{nlh} f_p \left(0.31 + \frac{L}{2800}\right) f_m C_w L^2 T_{LC} C_B$$

where:

f_{nlh} : Coefficient considering nonlinear effect to be taken as:

f_{nlh} = 0.9 for strength assessment

f_{nlh} = 1.0 for fatigue assessment

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[(0.2+0.04 f_T)+(11-8f_T)L\times10^{-5}]$ for fatigue assessment.

f_m : Distribution factor defined in [3.1.1].

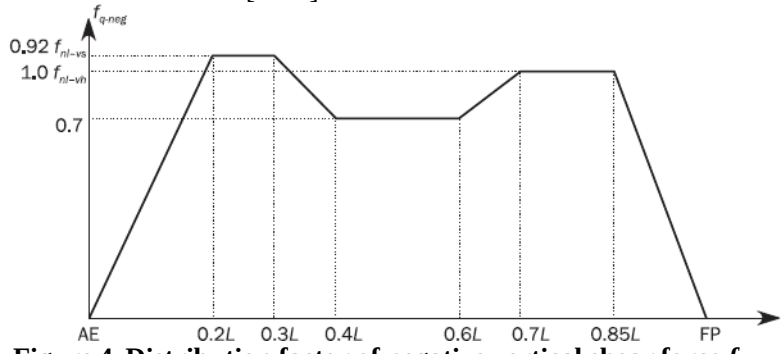


Figure 4 Distribution factor of negative vertical shear force $f_{q\text{-}neg}$

3.4 Wave torsional moment

3.4.1

The wave torsional moment at any longitudinal position with respect to the ship baseline, in kNm, is to be taken as:

$M_{wt}=f_p(M_{wt1}+M_{wt2})$

where:

$$M_{wt1} = 0.4 f_{t1} C_w \sqrt{\frac{L}{T_{LC}}} B^2 D C_B$$

$M_{wt2}=0.22 f_{t2} C_w L B^2 C_B$

f_{t1}, f_{t2} : Distribution factors, taken as:

$f_{t1}=0$ for $x<0$

$$f_{t1} = \left|\sin\left(\frac{2\pi x}{L}\right)\right| \text{ for } 0 \leqslant x \leqslant L$$

$f_{t1}=0$ for $x>L$

$f_{t2}=0$ for $x<0$

$$f_{t2} = \sin^2\left(\frac{\pi x}{L}\right) \quad \text{for } 0 \leqslant x \leqslant L$$

$f_{t2}=0$ for $x>L$

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[0.2+(5\, f_T - 4.25)B\times 10^{-4}]$ for fatigue assessment

3.5 Hull girder loads for dynamic load cases

3.5.1 General

The dynamic hull girder loads to be applied for the dynamic load cases defined in Ch 4, Sec 2, are given in [3.5.2] to [3.5.5].

3.5.2 Vertical wave bending moment

The vertical wave bending moment, $M_{wv\text{-}LC}$, in kNm, to be used for each dynamic load case in Ch 4, Sec2, is defined in Table 1.

Vertical wave bending moment for dynamic load cases **Table 1**

Load combination factor	$M_{wv\text{-}LC}$
$C_{WV} \geqslant 0$	$f_\beta C_{WV} M_{wv-h}$
$C_{WV} < 0$	$f_\beta C_{WV} \lvert M_{wv-s} \rvert$

where:

C_{WV} : Load combination factor for vertical wave bending moment, to be taken as specified in Ch 4, Sec 2.

$M_{wv\text{-}h}$, $M_{wv\text{-}s}$: Hogging and sagging vertical wave bending moment taking account of the considered design load scenario, as defined in [3.1.1].

3.5.3 Vertical wave shear force

The vertical wave shear force, $Q_{wv\text{-}LC}$, in kN, to be used for each dynamic load case in Ch 4, Sec 2, is defined inTable 2.

Vertical wave shear force for dynamic load cases **Table 2**

Load combination factor	$Q_{wv\text{-}LC}$
$C_{QW} \geqslant 0$	$f_\beta C_{QW} Q_{wv-pos}$
$C_{QW} < 0$	$f_\beta C_{QW} \lvert Q_{wv-neg} \rvert$

where:

C_{QW} : Load combination factor for vertical wave shear force, to be taken as specified in Ch 4, Sec 2.

$Q_{wv\text{-}pos}$, $Q_{wv\text{-}neg}$: Positive and negative vertical wave shear force taking account of the considered design load scenario, as defined in [3.2.1].

3.5.4 Horizontal wave bending moment

The horizontal wave bending moment, $M_{wh\text{-}LC}$, in kNm, to be used for each dynamic load case defined in Ch4, Sec 2, is to be taken as:

$M_{wh\text{-}LC}=f_\beta C_{WH} M_{wh}$

where:

C_{WH} : Load combination factor for horizontal wave bending moment, to be taken as specified in Ch 4, Sec 2.

M_{wh} : Horizontal wave bending moment taking account of the appropriate design load scenario, as defined in [3.3.1].

3.5.5 Wave torsional moment

The wave torsional moment, $M_{wt\text{-}LC}$, in kNm, to be used for each dynamic load case defined in Ch 4, Sec 2, is to be taken as:

$M_{wt\text{-}LC}=f_\beta C_{WT} M_{wt}$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Ch 4, Sec 2.
M_{wt} : Wave torsional moment taking account of the appropriate design load scenario, as defined in [3.4.1].

Section 5 EXTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

λ : Wave length, in m.

B_x : Moulded breadth at the waterline, in m, at the considered cross section.

x, y, z: X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

f_{xL} : Ratio as defined in Ch 4, Sec 2.

f_{yB} : Ratio between Y-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x}, \text{ but not greater than 1.0,}$$

f_{yB} = 1.0 when B_x =0.

f_{yB1} : Ratio between Y-coordinate of the load point and B, to be taken as:

$$f_{yB} = \frac{|2y|}{B}, \text{ but not greater than 1.0}$$

C_w : Wave coefficient defined in Ch 4, Sec 4.

f_T : Ratio as defined in Ch 4, Sec 3.

$P_{W,WL}$: Wave pressure at the waterline, kN/m^2, for the considered dynamic load case.

$P_{W,WL}=P_W$ for $y=B_x/2$ and $z = T_{LC}$

h_W : Water head equivalent to the pressure at waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g}$$

f_{ps} : Coefficient for strength assessment, as defined in Ch 4, Sec 3.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

T : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

f_{fa} : Coefficient defined in Ch 4, Sec 3.

f : Coefficient defined in Ch 4, Sec 4.

z_{SD} : Z coordinate, in m, of the midpoint of stiffener span, or of the middle of the elementary plate panel.

1 SEA PRESSURE

1.1 Total pressure

1.1.1

The external pressure P_{ex} at any load point of the hull, in kN/m^2, for the static (S) design load scenarios, is to be taken as:

$P_{ex} = P_S$,but not less than 0.

The total pressure P_{ex} at any load point of the hull for the static plus dynamic (S+D) design load scenarios, is to be derived from each dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$, but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in [1.2].

P_W : Wave pressure, in kN/m^2, is defined in [1.3].

1.2 Hydrostatic pressure

1.2.1

The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Hydrostatic pressure, P_S **Table 1**

Location	Hydrostatic Pressure, P_S, in kN/m^2
$z \leqslant T_{LC}$	$\rho g(T_{LC}-z)$
$z > T_{LC}$	0

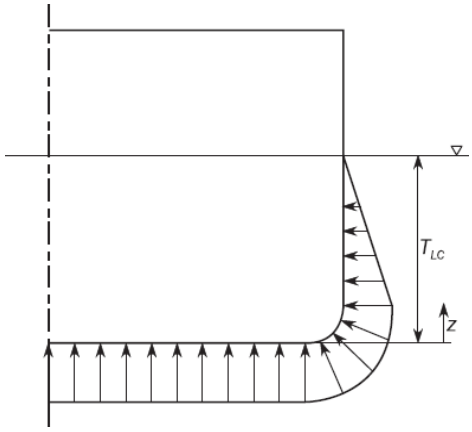


Figure 1 Hydrostatic pressure, P_S

1.3 External dynamic pressures for strength assessment

1.3.1 General

The hydrodynamic pressures for each dynamic load case defined in Ch4, Sec 2, [2] are defined in [1.3.2] to [1.3.8].

1.3.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, *PW*, for HSM-1 and HSM-2 load cases, at any load point, in kN/m2, are to be obtained from Table 2. See also Figure 2 and Figure 3.

Hydrodynamic pressures for HSM load cases **Table 2**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - g(z-T_{LC})$	$P_W = 0$
HSM-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_\beta f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:

- For extreme sea loads design load scenario:
  f_{nl} = 0.7 at f_{XL}= 0.0
  f_{nl} = 0.9 at f_{XL}= 0.3
  f_{nl} = 0.9 at f_{XL}= 0.7
  f_{nl} = 0.6 at f_{XL}= 1.0
- For ballast water exchange design load scenario:
  f_{nl} = 0.85 at f_{XL}= 0.0
  f_{nl} = 0.95 at f_{XL}= 0.3
  f_{nl} = 0.95 at f_{XL}= 0.7
  f_{nl} = 0.80 at f_{XL}= 1.0
  Intermediate values are obtained by linear interpolation.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:
f_h=3.0(1.21-0.66f_T)

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left\{(3 - 2\sqrt{f_{yB}}) - \frac{20}{9} f_{xL}(7 - 6\sqrt{f_{yB}})\right\} + \frac{2}{3}(1 - f_T) \quad \text{for} \quad f_{xL} < 0.15$$

k_a=1.0 for $0.15 \leqslant f_{xL} < 0.7$

$$k_a = 1 + (f_{xL} - 0.7)\left\{\left(\frac{40}{3} f_T - 5\right) + 2(1 - f_{yB})\left[\frac{18}{C_B} f_T (f_{xL} - 0.7) - 0.25(2 - f_T)\right]\right\} \text{ for } f_{xL} \geqslant 0.7$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.6(1+f_T)L$

k_p : Phase coefficient to be obtained from Table 3. Intermediate values are to be interpolated.

k_p values for HSM load cases **Table 3**

f_{xL}	0	0.3 – 0.1 f_T	0.35 – 0.1 f_T	0.8 – 0.2 f_T	0.9 – 0.2f_T	1.0
k_p	–0.25 f_T (1 + f_{yB})	-1	1	1	-1	-1

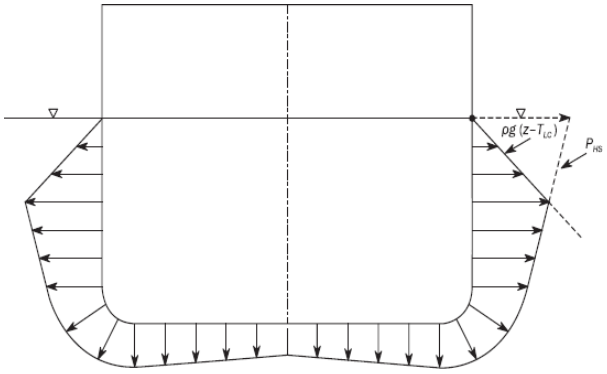


Figure 2 Transverse distribution amidships of dynamic pressure for HSM-1, HSA-1 and FSM-1 load cases

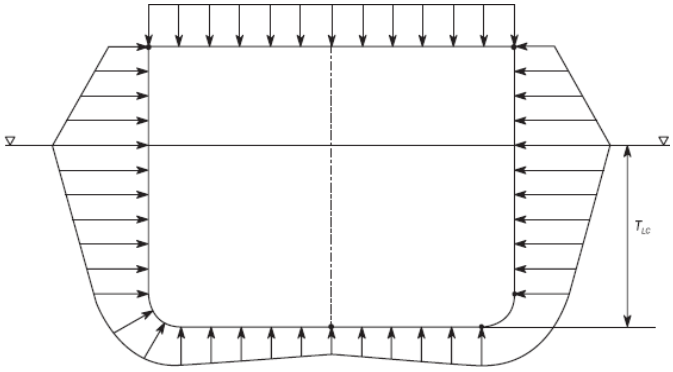


Figure 3 Transverse distribution amidships of dynamic pressure for HSM-2, HSA-2 and FSM-2 load cases

1.3.3 Hydrodynamic pressures for HSA load cases

The hydrodynamic pressures, P_W, for HSA-1 and HSA-2 load cases at any load point, in kN/m^2, are to be obtained from Table 4. See also Figure 2 and Figure 3.

Hydrodynamic pressures for HSA load cases **Table 4**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
HSA-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - g(z-T_{LC})$	$P_W = 0$
HSA-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as defined in [1.3.2].

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

f_h=2.4(1.21-0.66f_T)

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as defined in [1.3.2].

λ : Wave length of the dynamic load case, in m, to be taken as:

λ=0.6(1+f_T)L

k_p : Phase coefficient to be obtained from Table 5. Intermediate values are to be interpolated.

k_p values for HSA load cases **Table 5**

f_{xL}	0	0.3 – 0.1 f_T	0.5 – 0.2 f_T	0.8 – 0.2 f_T	0.9 – 0.2 f_T	1.0
k_P	$1.5-f_T-0.5f_{yB}$	-1	1	1	-1	-1

1.3.4 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 6. See also Figure 2 and Figure 3.

Hydrodynamic pressures for FSM load cases **Table 6**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
FSM-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - g(z-T_{LC})$	$P_W = 0$
FSM-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{FS} = f_\beta f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:

f_{nl} = 0.9 for extreme sea loads design load scenario.

f_{nl} = 0.95 for ballast water exchange design load scenarios.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

f_h = 2.6

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

k_a = 1+(3.75-2f_T)(1-5f_{xL})(1-f_{yB}) for f_{xL}<0.2

k_a=1.0 for 0.2$\leqslant f_{xL}$<0.9

k_a = 1+20 (1-f_{yB}) (f_{xL}-0.9) for $f_{xL} \geqslant$0.9

λ : Wave length of the dynamic load case, in m, to be taken as:

λ=0.6(1+2/3f_T)L

k_p : Phase coefficient to be obtained from Table 7. Intermediate values are to be interpolated.

k_p values for FSM load cases **Table 7**

f_{xL}	0	0.35 – 0.1 f_T	0.5 – 0.2 f_T	0.75	0.8	1.0
k_p	$-0.75-0.25f_{yB}$	-1	1	1	-1	$-0.75-0.25f_{yB}$

1.3.5 Hydrodynamic pressures for BSR load cases

The wave pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 8. See also Figure 4 and Figure 5.

Hydrodynamic pressures for BSR load cases **Table 8**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
BSR-1P	$P_W = \max(P_{BSR}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
BSR-2P	$P_W = \max(-P_{BSR}, \rho g(z-T_{LC}))$		
BSR-1S	$P_W = \max(P_{BSR}, \rho g(z-T_{LC}))$		
BSR-2S	$P_W = \max(-P_{BSR}, \rho g(z-T_{LC}))$		

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = f_\beta f_{nl}\left(10y\sin\theta + 0.88 f_{ps} C_w \sqrt{\frac{L_0+\lambda-125}{L}}(f_{yB1}+1)\right)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = f_\beta f_{nl}\left(-10y\sin\theta + 0.88 f_{ps} C_w \sqrt{\frac{L_0+\lambda-125}{L}}(f_{yB1}+1)\right)$$

f_{nl} : Coefficient considering non-linear effect, to be taken as:
f_{nl} = 1 for extreme sea loads design load scenario.
f_{nl} = 1 for ballast water exchange design load scenarios.

λ :Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_\beta^2$$

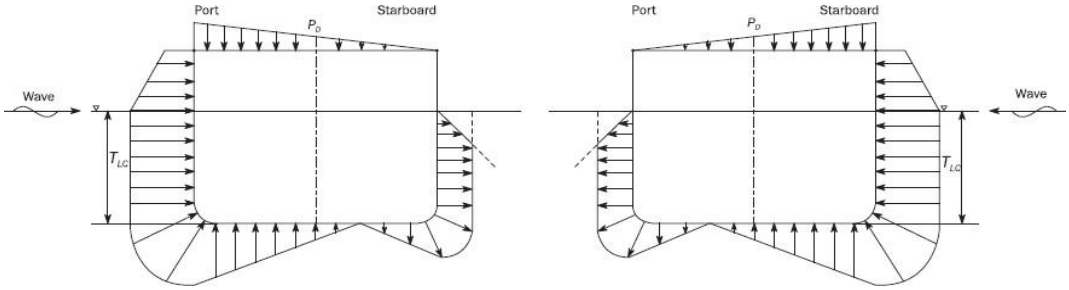


Figure 4 Transverse distribution of dynamic pressure for BSR-1P (left) and BSR-1S (right) load cases

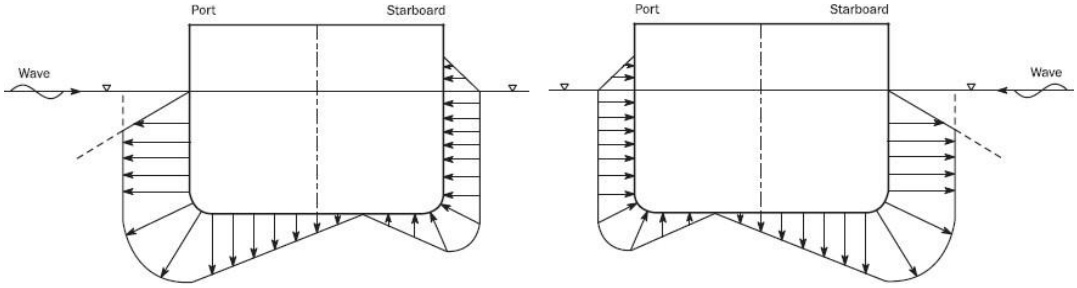


Figure 5 Transverse distribution of dynamic pressure for BSR-2P (left) and BSR-2S (right) load cases

1.3.6 Hydrodynamic pressures for BSP load cases

The wave pressures, *PW*, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 9. See also Figure 6 and Figure 7.

Hydrodynamic pressures for BSP load cases **Table 9**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$z \leqslant T_{LC}$	$z \leqslant T_{LC}$
BSP-1P	P_W = max (P_{BSP}, $\rho g(z-T_{LC})$)	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
BSP-2P	P_W = max (-P_{BSP}, $\rho g(z-T_{LC})$)		
BSP-1S	P_W = max (P_{BSP} , $\rho g(z-T_{LC})$)		
BSP-2S	P_W = max (-P_{BSP} , $\rho g(z-T_{LC})$)		

where:

$$P_{BSP} = 4.5 f_\beta f_{ps} f_{nl} f_{yz} C_w \sqrt{\frac{L_0+\lambda-125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.2(1+2f_T)L$

f_{yz}: Girth distribution coefficient, to be obtained from Table 10.

Girth distribution coefficient, f_{yz} for BSP load cases **Table 10**

Transverse position	BSP-1P，BSP-2P	BSP-1S，BSP-2S
$y \geq 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$
$y < 0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$

fnl : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:
  f_{nl} = 0.6 at f_{XL} = 0.0
  f_{nl} = 0.8 at f_{XL} = 0.3
  f_{nl} = 0.8 at f_{XL} = 0.7
  f_{nl} = 0.6 at f_{XL} = 1.0
- For ballast water exchange design load scenario:
  f_{nl} = 0.6 at f_{XL}= 0.0
  f_{nl} = 0.8 at f_{XL}= 0.3
  f_{nl} = 0.8 at f_{XL}= 0.7
  f_{nl} = 0.6 at f_{XL}= 1.0

Intermediate values are obtained by linear interpolation.

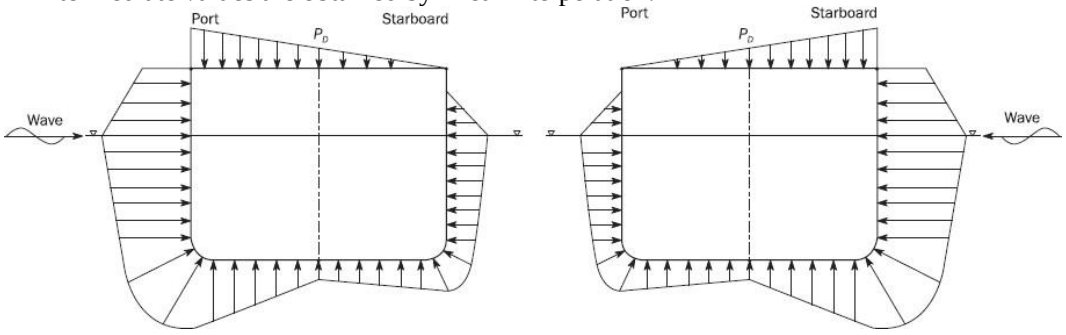


Figure 6 Transverse distribution of dynamic pressure for BSP-1P (left) and BSP-1S (right) load cases

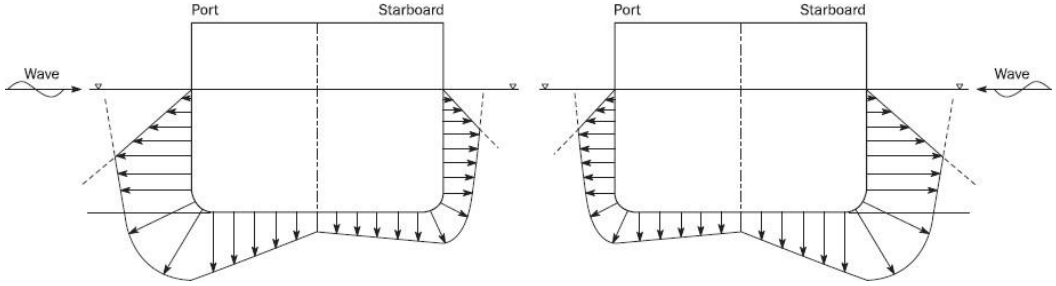


Figure 7 Transverse distribution of dynamic pressure for BSP-2P (left) and BSP-2S (right) load cases

1.3.7 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point are to be obtained, in kN/m^2, from Table 11. See also Figure 8 and Figure 9.

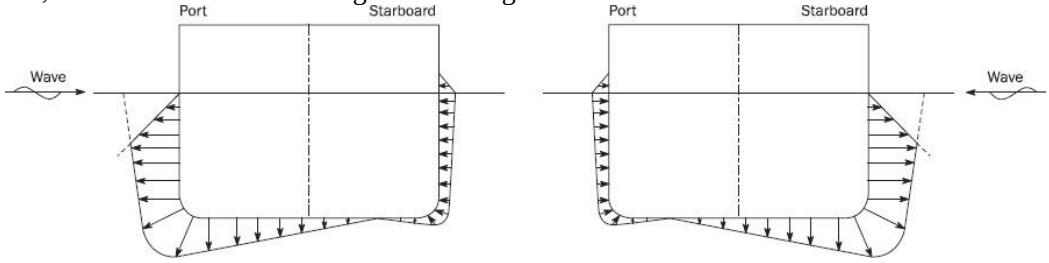


Figure 8 Transverse distribution of dynamic pressure amidships for OST-1P (left) and OST-1S (right) load cases

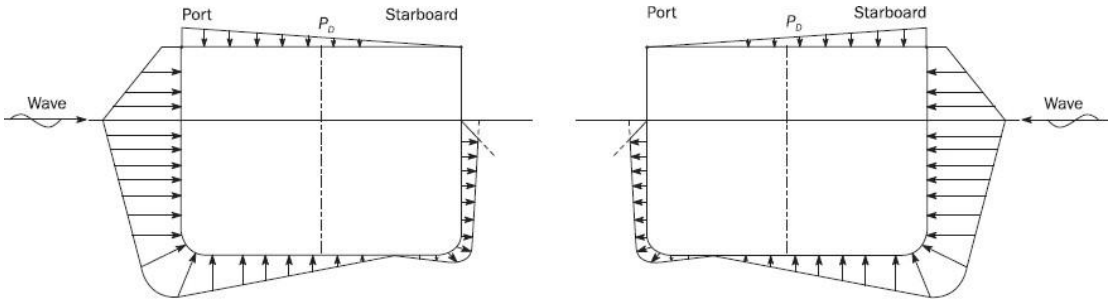


Figure 9 Transverse distribution of dynamic pressure amidships for OST-2P (left) and OST-2S (right) load cases

Hydrodynamic pressures for OST load cases **Table 11**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
OST-1P	P_W = max (P_{OST}, $\rho g(z-T_{LC})$)	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
OST-2P	P_W = max (-P_{OST}, $\rho g(z-T_{LC})$)		
OST-1S	P_W = max (P_{OST} , $\rho g(z-T_{LC})$)		
OST-2S	P_W = max (-P_{OST} , $\rho g(z-T_{LC})$)		

where:

$$P_{OST} = 1.38 f_{ps} f_{nl} k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 12.

f_{nl} : Coefficient considering non-linear effect, to be taken as:

f_{nl} = 0.8 for extreme sea loads design load scenario.

f_{nl} = 0.9 for ballast water exchange design load scenarios.

λ : Wave length of the dynamic load case, in m, to be taken as:

λ= 0.45 L

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 13.

k_p : Phase coefficient to be obtained from Table 14. Intermediate values are to be interpolated.

Girth distribution coefficient, f_{yz} for OST load cases **Table 12**

Transverse position	OST-1P，OST-2P	OST -1S，OST -2S
$y \geq 0$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$	$1.5\frac{z}{T_{LC}} + 1.5$
$y < 0$	$1.5\frac{z}{T_{LC}} + 1.5$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$

k_a values for OST load cases **Table 13**

Transverse position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	$f_{xL} \leqslant 0.2$	$1.0+3.5(1-f_{yB})(1-5f_{xL})$	$1.0+[3.5-(4f_T-0.5)f_{yB}](1-5f_{xL})$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1.0+4(1-f_T)(5f_{xL}-4)f_{yB}$
$y < 0$	$f_{xL} \leqslant 0.2$	$1.0+[3.5-(4f_T-0.5)f_{yB}](1-5f_{xL})$	$1.0+3.5(1-f_{yB})(1-5f_{xL})$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1.0+4(1-f_T)(5f_{xL}-4)f_{yB}$	1.0

k_p values for OST load cases **Table 14**

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	0.0	1.0	1.0

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
	0.2	1.0	$1.0+(0.75-1.5\ f_T)f_{yB}$
	0.4	-1.0	$-1.0+(1.75-0.5\ f_T)f_{yB}$
	0.5	-1.0	$1.0+(0.75-1.5\ f_T)f_{yB}$
	0.7	$-0.1+(1.6\ f_T-1.5)f_{yB}$	$-0.1+(0.25-0.3\ f_T)f_{yB}$
	0.9	$0.8+0.2f_{yB}$	$0.8-(0.9\ f_T+0.85)f_{yB}$
	1.0	$-1.0+f_{yB}$	$-1.0+(0.5-0.5\ f_T)f_{yB}$
$y<0$	0.0	1.0	1.0
	0.2	$1.0+(0.75-1.5\ f_T)f_{yB}$	1.0
	0.4	$-1.0+(1.75-0.5\ f_T)f_{yB}$	-1.0
	0.5	$-1.0+(1.75-0.5\ f_T)f_{yB}$	-1.0
	0.7	$-0.1+(0.25-0.3\ f_T)f_{yB}$	$-1.0+(1.6\ f_T-1.5)f_{yB}$
	0.9	$0.8-(0.9\ f_T+0.85)f_{yB}$	$0.8+0.2f_{yB}$
	1.0	$-1.0+(0.5-0.5\ f_T)f_{yB}$	$-1.0+f_{yB}$

1.3.8 Hydrodynamic pressures for OSA load cases

The wave pressures, P_W, for OSA-1 and OSA-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 15. See also Figure 10 and Figure 11.

Hydrodynamic pressures for OSA load cases **Table 15**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant h_W+T_{LC}$	$z>h_W+T_{LC}$
OSA-1P	$P_W = \max(P_{OSA}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
OSA-2P	$P_W = \max(-P_{OSA}, \rho g(z-T_{LC}))$		
OSA-1S	$P_W = \max(P_{OSA}, \rho g(z-T_{LC}))$		
OSA-2S	$P_W = \max(-P_{OSA}, \rho g(z-T_{LC}))$		

where:

$$P_{OSA} = 0.8 f_{ps} f_{nl} k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(1 + 0.5 f_T)$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.7L$

f_{nl} : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:
  f_{nl} = 0.5 at f_{XL}= 0.0
  f_{nl} = 0.8 at f_{XL}= 0.3
  f_{nl} = 0.8 at f_{XL}= 0.7
  f_{nl} = 0.6 at f_{XL}= 1.0
- For ballast water exchange design load scenario:
  f_{nl} = 0.75 at f_{XL}= 0.0
  f_{nl} = 0.9 at f_{XL}= 0.3
  f_{nl} = 0.9 at f_{XL}= 0.7
  f_{nl} = 0.8 at f_{XL}= 1.0

  Intermediate values are obtained by linear interpolation.

fyz : Girth distribution coefficient, to be obtained from Table 16.

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 17.

k_p : Phase coefficient to be obtained from Table 18. Intermediate values are to be interpolated.

Girth distribution coefficient, f_{yz} for OSA load cases **Table 16**

Transverse position	OSA-1P, OSA-2P	OSA -1S, OSA -2S
$y \geqslant 0$	$5.5\frac{z}{T_{LC}} + 5.3f_{yB} + 2.2$	$0.9\frac{z}{T_{LC}} + 0.4f_{yB} + 2.2$
$y<0$	$0.9\frac{z}{T_{LC}} + 0.4f_{yB} + 2.2$	$5.5\frac{z}{T_{LC}} + 5.3f_{yB} + 2.2$

k_a values for OSA load cases **Table 17**

Transverse position	Longitudinal position	OSA-1P - OSA-2P	OSA-1S - OSA-2S
$y \geqslant 0$	$f_{xL} \leqslant 0.2$	$1.0+3(2-f_T)(1-5f_{xL})(1-f_{yB})$	$1.0+3(2-f_T)(1-5f_{xL})+\{(28f_{xL}-5)+3f_T(1-5f_{xL})\}f_{yB}$
	$0.2<f_{xL} \leqslant 0.5$	1.0	$1.0+(1-2f_{xL})f_{yB}$
	$0.5<f_{xL} \leqslant 0.8$	1.0	$1.0+1.5(2f_{xL}-1)f_{yB}$
	$f_{xL} \geqslant 0.8$	$1.0+(f_{xL}-0.8)(1-f_{yB})A$	$1.0+\{1.5(2f_{xL}-1)-(f_{xL}-0.8)A)\}f_{yB}+(f_{xL}-0.8)A$
$y<0$	$f_{xL} \leqslant 0.2$	$1.0+3(2-f_T)(1-5f_{xL})+\{(28f_{xL}-5)+3f_T(1-5f_{xL})\}f_{yB}$	$1.0+3(2-f_T)(1-5f_{xL})(1-f_{yB})$
	$0.2<f_{xL} \leqslant 0.5$	$1.0+(1-2f_{xL})f_{yB}$	1.0
	$0.5<f_{xL} \leqslant 0.8$	$1.0+1.5(2f_{xL}-1)f_{yB}$	1.0
	$f_{xL} \geqslant 0.8$	$1.0+\{1.5(2f_{xL}-1)-(f_{xL}-0.8)A)\}f_{yB}+(f_{xL}-0.8)A$	$1.0+(f_{xL}-0.8)(1-f_{yB})A$
where: $A=22-15f_T+3[22(f_{xL}-0.8)-0.25(2-f_T)]$			

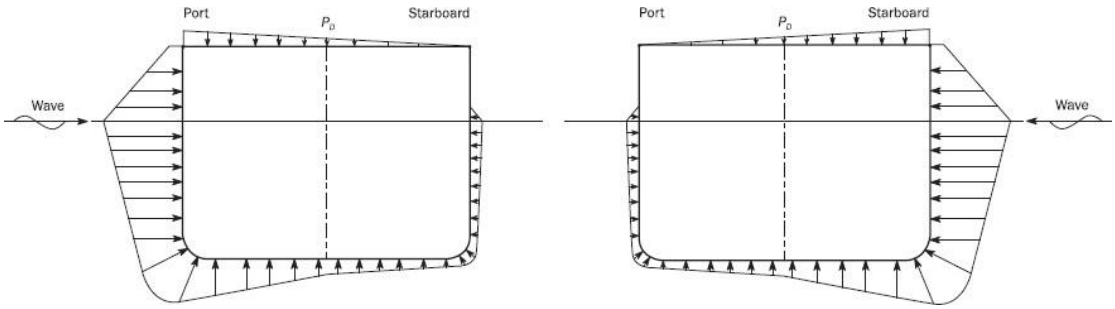


Figure 10 Transverse distribution of dynamic pressure amidships for OSA-1P (left) and OSA-1S (right) load cases

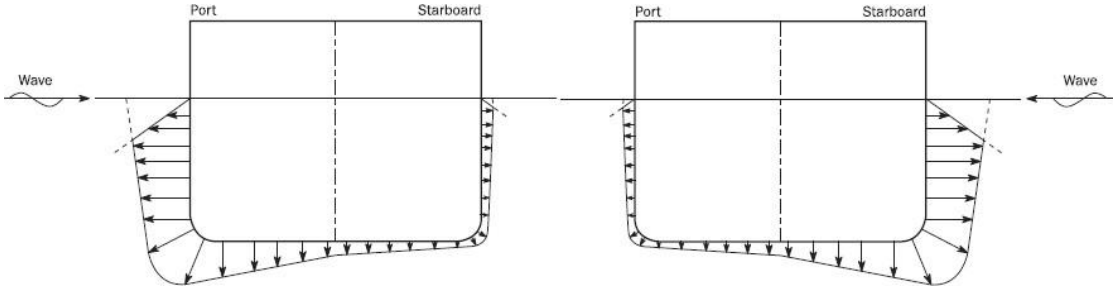


Figure 11 Transverse distribution of dynamic pressure amidships for OSA-2P (left) and OSA-2S (right) load cases

k_p values for OSA load cases **Table 18**

Transverse position	f_{xL}	OSA-1P; OSA-2P	OSA-1S; OSA-2S
$y \geqslant 0$	0.0	$0.75\text{-}f_{yB}$	0.75
	0.2	$f_T\text{-}0.25+(1.25\text{-}f_T)f_{yB}$	$f_T\text{-}0.25+(0.35f_T\text{-}0.47)f_{yB}$
	0.4	1.0	$1.0+(2.7f_T\text{-}3.2)f_{yB}$
	0.5	$1.25\text{-}0.5f_T+(0.5f_T\text{-}0.25)f_{yB}$	$1.25\text{-}0.5f_T+(2.7f_T\text{-}3.2)f_{yB}$
	0.6	$1.5\text{-}f_T+(f_T\text{-}1.07)f_{yB}$	$1.5\text{-}f_T+(2.68f_T\text{-}3.19)f_{yB}$
	0.85	$0.5f_T\text{-}1.25+(0.25\text{-}0.5f_T)f_{yB}$	$0.5f_T\text{-}1.25+(0.2\text{-}0.1f_T)f_{yB}$
	1.0	$0.5f_T\text{-}1.25+(0.25\text{-}0.5f_T)f_{yB}$	$0.5f_T\text{-}1.25+(0.2\text{-}0.1f_T)f_{yB}$
$y<0$	0.0	0.75	$0.75\text{-}0.5f_{yB}$
	0.2	$f_T\text{-}0.25+(0.35f_T\text{-}0.47)f_{yB}$	$f_T\text{-}0.25+(1.25\text{-}f_T)f_{yB}$
	0.4	$1.0+(2.7f_T\text{-}3.2)f_{yB}$	1.0
	0.5	$1.5\text{-}0.5f_T+(2.7f_T\text{-}3.2)f_{yB}$	$1.25\text{-}0.5f_T+(0.5f_T\text{-}0.25)f_{yB}$
	0.6	$1.5\text{-}f_T+(2.68f_T\text{-}3.19)f_{yB}$	$1.5\text{-}f_T+(f_T\text{-}1.07)f_{yB}$
	0.85	$0.5f_T\text{-}1.25+(0.2\text{-}0.1f_T)f_{yB}$	$0.5f_T\text{-}1.25+(0.25\text{-}0.5f_T)f_{yB}$
	1.0	$0.5f_T\text{-}1.25+(0.2\text{-}0.1f_T)f_{yB}$	$0.5f_T\text{-}1.25+(0.25\text{-}0.5f_T)f_{yB}$

1.3.9 Envelope of dynamic pressure

The envelope of dynamic pressure at any point, *Pex-max*, is to be taken as the greatest pressure obtained from any of the load cases determined by [1.3.2] to [1.3.8].

1.4 External dynamic pressures for fatigue assessments

1.4.1 General

The external pressure P_{ex} at any load point of the hull for the fatigue static plus dynamic (F:S+D) design load scenario, is to be derived for each fatigue dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$ but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in [1.2].

P_W : Hydrodynamic pressure, in kN/m^2, is defined in [1.4.2] to [1.4.6].

1.4.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for load cases HSM-1 and HSM-2, at any load point, in kN/m^2, are to be obtained from Table 19.

Hydrodynamic pressures for HSM load cases **Table 19**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
HSM-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z-T_{LC})$	$P_W = 0$
HSM-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_p f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz}: Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

$f_h = 2.75(1.21\text{-}0.66f_T)$

f_p: Coefficient to be taken as:

$f_p=f_{fa}[(0.21+0.02f_T)+(6-4f_T)L\times10^{-5}]$

k_a: Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a=1+3f_T-(1+f_T)f_{yB}+[5(1+f_T)f_{yB}-15f_T]f_{xL}$ for $f_{xL}<0.2$

$k_a=1.0$ for $0.2\leqslant f_{xL}<0.6$

$k_a=1+(f_{xL}-0.6)[(13.5-3.5f_T)f_{yB}+(14.5f_T-17)+40(1-f_{yB})(f_{xL}-0.6)]$ for $f_{xL}\geqslant0.6$

λ: Wave length of the dynamic load case, in m, to be taken as:

$\lambda=0.6(1+f_T)L$

k_p : Phase coefficient to be obtained from Table 20. Intermediate values are to be interpolated.

k_p values for HSM load cases **Table 20**

f_{xL}	k_P
0	$(1.0-f_T)+(0.5-f_T)f_{yB}$
$0.3-0.1f_T$	-1
$0.5-0.2f_T$	1
$0.9-0.4f_T$	1
$0.9-0.2f_T$	-1
1.0	-1

1.4.3 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 21.

Hydrodynamic pressures for FSM load cases **Table 21**

	Wave pressure, in kN/m^2		
Load case	$z\leqslant T_{LC}$	$T_{LC}<z\leqslant2h_W+T_{LC}$	$z>2h_W+T_{LC}$
FSM-1	$P_W=\max(-P_{FS},\rho g(z-T_{LC}))$	$P_W=P_{W,WL}-\frac{1}{2}\rho g(z-T_{LC})$	$P_W=0$
FSM-2	$P_W=\max(P_{FS},\rho g(z-T_{LC}))$		

where:

$$P_{FS}=f_p f_h k_a k_p f_{yz} C_w\sqrt{\frac{L_0+\lambda-125}{L}}$$

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz}=\frac{z}{T_{LC}}+f_{yB}+1$$

f_h : Coefficient to be taken as:

$f_h=2.6$

f_p : Coefficient to be taken as:

$f_p=f_{fa}[(0.21+0.02f_T)+(6-4f_T)L\times10^{-5}]$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a=1+(3.5-2f_T)(1-5f_{xL})(1-f_{yB})$ for $f_{xL}<0.2$

$k_a=1.0$ for $0.2\leqslant f_{xL}<0.9$

$k_a=1+15(1-f_{yB})(f_{xL}-0.9)$ for $f_{xL}\geqslant0.9$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda=0.6\left(1+\frac{2}{3}f_T\right)L$$

k_p : Phase coefficient to be obtained from Table 22. Intermediate values are to be interpolated.

k_p values for FSM load cases **Table 22**

f_{xL}	k_P
0	$-0.75-0.25f_{yB}$
$0.35-0.1f_T$	-1

f_{xL}	k_P
$0.5 - 0.2f_T$	1
0.75	1
$0.9 - 0.1f_T$	-1
1.0	$-0.5 - 0.5\,f_{yB}$

1.4.4 Hydrodynamic pressures for BSR load cases

The hydrodynamic pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 23.

Hydrodynamic pressures for BSR load cases **Table 23**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSR-1P	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0$
BSR-2P	$P_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		
BSR-1S	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$		
BSR-2S	$p_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = 10y\sin\theta + 0.88 f_p C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB} + 1)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = -10y\sin\theta + 0.88 f_p C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB} + 1)$$

f_p : Coefficient to be taken as:
$f_p = f_{fa}[(0.21 + 0.04f_T) - (12f_T - 2)B \times 10^{-4}]$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_\theta^2$$

1.4.5 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 24.

Hydrodynamic pressures for BSP **Table 24**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		

where:

$$P_{BSP} = 0.45 f_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.2(1 + 2f_T)L$

f_p : Coefficient to be taken as:
$f_p = f_{fa}[0.2 + (8 + 16f_T) \times 10^{-3}]$

f_{yz} : Girth distribution coefficient, to be obtained from Table 25.

Girth distribution coefficient, f_{yz} for BSP load case **Table25**

Transverse position	BSP-1P，BSP-2P	BSP-1S，BSP-2S
$y \geqslant 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$
$y<0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$

1.4.6 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 26.

Hydrodynamic pressures for OST load cases **Table 26**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
OST-1P	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0$
OST-2P	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		
OST-1S	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$		
OST-2S	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		

where:

$$P_{OST} = 1.38 f_p k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 27.

Girth distribution coefficient, f_{yz} for OST load cases **Table 27**

Transverse position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	$5\frac{z}{T_{LC}} + 3.3 f_{yB} + 1.7$	$\frac{z}{T_{LC}} + 0.3 f_{yB} + 1.7$
$y<0$	$\frac{z}{T_{LC}} + 0.3 f_{yB} + 1.7$	$5\frac{z}{T_{LC}} + 3.3 f_{yB} + 1.7$

f_p : Coefficient to be taken as:

$f_p = f_{fa}[(0.25 - 0.02 f_T) + (12 f_T - 9) B \times 10^{-4}]$

λ : Wave length of the dynamic load case, in m, to be taken as:

$\lambda = 0.45L$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 28.

k_p : Phase coefficient to be obtained from Table 29. Intermediate values are to be interpolated.

k_a values for OST load cases **Table 28**

Transverse Position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	$f_{xL} \leqslant 0.2$	$1.0 + \{(3.5 - 2 f_T) + (10 f_T - 17.5)\} f_{xL}(1 - f_{yB})$	$1.0 + (3.5 - 2 f_T - 1.5 f_{yB}) + (10 f_T - 17.5 + 7.5 f_{yB}) f_{xL}$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1.0 + 2(1 - f_T)(5 f_{xL} - 4) f_{yB}$
$y<0$	$f_{xL} \leqslant 0.2$	$1.0 + (3.5 - 2 f_T - 1.5 f_{yB}) + (10 f_T - 17.5 + 7.5 f_{yB}) f_{xL}$	$1.0 + \{(3.5 - 2 f_T) + (10 f_T - 17.5)\} f_{xL}(1 - f_{yB})$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1.0 + 2(1 - f_T)(5 f_{xL} - 4) f_{yB}$	1.0

k_p values for OST load cases **Table 29**

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	0.0	1.0	$1.0+(0.5-f_T)f_{yB}$
	0.2	1.0	$1.0+3(0.5-f_T)f_{yB}$
	0.4	-1.0	$(2.7-2.4f_T)f_{yB}-1$
	0.5	-1.0	$(2.8-2.6f_T)f_{yB}-1$
	0.7	$(f_T-0.62)f_{yB}-0.38$	$(2.38-3f_T)f_{yB}-0.38$
	0.9	$0.24+0.76\ f_{yB}$	$0.24-(0.24+f_T)f_{yB}$
	1.0	$-1.0+0.5f_{yB}$	-1.0
$y<0$	0.0	$1.0+(0.5-f_T)f_{yB}$	1.0
	0.2	$1.0+3(0.5-f_T)f_{yB}$	1.0
	0.4	$(2.7-2.4f_T)f_{yB}-1$	-1.0
	0.5	$(2.8-2.6f_T)f_{yB}-1$	-1.0
	0.7	$(2.38-3f_T)f_{yB}-0.38$	$(f_T-0.62)f_{yB}-0.38$
	0.9	$0.24-(0.24+f_T)f_{yB}$	$0.24+0.76\ f_{yB}$
	1.0	–1.0	$-1.0+0.5f_{yB}$

2 EXTERNAL PRESSURES ON EXPOSED DECKS

2.1 Application

2.1.1

The external pressures and forces on exposed decks are only to be applied for strength assessment.

2.1.2

The green sea pressures defined in [2.2] for exposed decks are to be considered independently of the pressures due to distributed cargo or other equipment loads and any concentrated forces due to cargo or other unit equipment loads, defined in [2.3.1] and [2.3.2] respectively.

2.2 Green sea loads

2.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as defined in [2.2.3] to [2.2.4]

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck for the static (S) design load scenarios is zero.

2.2.2

If a breakwater is fitted on the exposed deck, no reduction in the green sea pressure is allowed for the area of the exposed deck located aft of the breakwater.

2.2.3 HSM, HSA and FSM load cases

The external pressure, P_D, for HSM, HSA and FSM load cases, at any load point of an exposed deck is to be obtained, in kN/m^2, from the following formula, see Figure 2 and Figure 3:

$P_D=\chi P_W$

where:

$P_W = P_{W,D}$, but not to be taken less than $P_{D\text{-}min}$.

$P_{W,D}$: Pressure, in kN/m^2, obtained at side of the exposed deck for HSM, HSA and FSM load cases as defined in [1.3].

$P_{D\text{-}min}$: Minimum exposed deck pressure, in kN/m^2, to be taken as:

- For cargo hold analysis according to Ch 7: $P_{D\text{-}min} = 0$.

- For other cases: $P_{D\text{-}min}$ as defined in Table 30.

χ : Coefficient defined in Table 31.

Minimum pressures on exposed decks for HSM, HSA, FSM load cases Table 30

Location	Minimum pressure on exposed deck, $P_{D\text{-}min}$, in kN/m^2	
	$L_{LL} \geq 100$m	$L_{LL} < 100$m
$x_{LL}/L_{LL} \leqslant 0.75$	34.3	$14.9 + 0.195\, L_{LL}$
$x_{LL}/L_{LL} > 0.75$	$34.3 + (14.8 + a(L_{LL} - 100))\left(4\frac{x_{LL}}{L_{LL}} - 3\right)$	$12.2 + \frac{L_{LL}}{9}\left(5\frac{x_{LL}}{L_{LL}} - 2\right) + 3.6\frac{x_{LL}}{L_{LL}}$

Where

a : Coefficient taken equal to:

$a = 0.356$ for Type A, Type B-60 and Type B-100 freeboard ships

$a = 0.0726$ for Type B freeboard ships.

x_{LL} : X-coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

Coefficient for pressure on exposed decks Table 31

Exposed deck location	χ
Freeboard deck	1.00
Superstructure deck including forecastle deck	0.75
1st tier of deckhouse	0.56
2nd tier of deckhouse	0.42
3rd tier of deckhouse	0.32
4th tier of deckhouse	0.25
5th tier of deckhouse	0.20
6th tier of deckhouse	0.15
7th tier of deckhouse and above	0.10

2.2.4 BSR, BSP, OST and OSA load cases

The external pressure, P_D, for BSR, BSP, OST and OSA load cases at any load point of an exposed deck is to be obtained, in kN/m^2, by linear interpolation between the pressures at the port and starboard deck edges (see also Figure 4, Figure 6, Figure 9 and Figure 10):

$P_{D,stb} = \chi P_{W,D\text{-}stb}$

$P_{D,pt} = \chi P_{W,D\text{-}pt}$

where:

$P_{W,D\text{-}stb}$: Pressure obtained at starboard deck edge for BSR, BSP, OST or OSA load cases as defined in [1.3], as appropriate.

$P_{W,D\text{-}pt}$: Pressure obtained at port deck edge for BSR, BSP, OST and OSA load cases as defined in [1.3], as appropriate.

χ : Coefficient defined in Table 31.

2.2.5 Envelope of dynamic pressures on exposed deck

The envelope of dynamic pressure at any point of an exposed deck, $P_{D\text{-}max}$, is to be taken as the greatest pressure obtained from any of the load cases determined by [2.2.3] and [2.2.4].

2.3 Load carried on exposed deck

2.3.1 Pressure due to distributed load

If a distributed load is carried on an exposed deck, for example deck cargo or other equipment, the static and dynamic pressures due to this distributed load are to be considered.

The total pressure, P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenario is to be taken as:

$P_{dl} = P_{dl\text{-}s}$

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenario is to be derived for each dynamic load case and is to be taken as:

$P_{dl}=P_{dl\text{-}s}+P_{dl\text{-}d}$

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m^2, due to the distributed load, to be defined by the Designer and, in general, but not less than 10kN/m^2.

$P_{dl\text{-}d}$: Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_Z}{g} P_{dl-s}$$

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the distributed load, for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

2.3.2 Concentrated force due to unit load

If a unit load, for example deck cargo, is carried on an exposed deck, the static and dynamic forces due to the unit load carried are to be considered.

The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, is to be taken as:

$F_U=F_{U\text{-}s}$

The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$F_U=F_{U\text{-}s}+F_{U\text{-}d}$

where:

$F_{U\text{-}s}$: Static force, in kN, due to the unit load to be taken equal to:

$F_U=m_U g$

$F_{U\text{-}d}$: Dynamic force, in kN, due to unit load to be taken equal to:

$F_{U\text{-}d}=m_U f_\beta a_Z$

m_U : Mass of the unit load carried, in t.

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

3 EXTERNAL IMPACT PRESSURES FOR THE BOW AREA

3.1 Application

3.1.1

The impact pressures for the bow area are only to be applied for strength assessment.

3.2 Bottom slamming pressure

3.2.1

The bottom slamming pressure P_{SL}, in kN/m^2, for the bottom slamming design load scenario is to be evaluated for the following two cases:

Case 1: An empty ballast tank or a void space in way of the bottom shell.

$$P_{SL} = 10g\sqrt{L} f_{SL} c_{SL-et} \quad \text{for } L < 170 \text{ m}$$

$$P_{SL} = 130 g f_{SL} c_{SL-et} e^{c1} \quad \text{for } L \geqslant 170 \text{ m}$$

Case 2: A full ballast tank in way of the bottom shell.

$$P_{SL} = 10g\sqrt{L} f_{SL} c_{SL-ft} - 1.25\rho g(z_{top} - z) \quad \text{for } L < 170 \text{ m}$$

$$P_{SL} = 130 g f_{SL} c_{SL-ft} e^{c1} - 1.25\rho g(z_{top} - z) \quad \text{for } L \geqslant 170 \text{ m}$$

where:

c_1 : Coefficient to be taken as:

$c_1=0$ for $L \leqslant 180$m

$c_1=-0.0125(L-180)^{0.705}$ for $L > 180$ m

$c_{SL\text{-}et}$: Slamming coefficient for case with an empty ballast tank or void space:

$$c_{SL-et} = 5.95 - 10.5\left(\frac{T_{F-e}}{L}\right)^{0.2}$$

$c_{SL\text{-}ft}$: Slamming coefficient for case with a full ballast tank:

$$c_{SL-ef} = 5.95 - 10.5\left(\frac{T_{F-f}}{L}\right)^{0.2}$$

f_{SL} : Longitudinal slamming distribution factor, to be taken as:

f_{SL}=0 for $x/L \leqslant 0.5$

f_{SL}=1.0 for x/L=0.5+c_2

f_{SL}=1.0 for x/L=0.65+c_2

f_{SL}=0.5 for $x/L \geqslant 1.0$

Intermediate values of f_{SL} are to be obtained by linear interpolation.

c_2 : Coefficient to be taken as:

$$c_2 = 0.33C_B + \frac{L}{2500} \text{ but not to be taken greater than 0.35}$$

$TF\text{-}e$: Design slamming draught at the FP to be provided by the Designer. $T_{F\text{-}e}$ is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where any of the ballast tanks within the bottom slamming region are empty. This includes all loading conditions with tanks inside the bottom slamming region that use the 'sequential' ballast water exchange method, if relevant.

$T_{F\text{-}f}$: Design slamming draught at the FP to be provided by the Designer. $T_{F\text{-}f}$ is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where all ballast tanks within the bottom slamming region are full. This includes all loading conditions with tanks inside the bottom slamming region that use the 'flow-through' ballast water exchange method, if relevant.

z_{top} : Z-coordinate of the highest point of the tank, excluding small hatchways, in m. For strength assessment of double bottom floors and girders, z_{top} is not to be taken greater than the double bottom height.

3.2.2 Loading manual information

The loading guidance information is to clearly state the design slamming draughts and the ballast water exchange method used for each ballast tank, if any.

3.3 Bow impact pressure

3.3.1 Design pressures

The bow impact pressure P_{FB}, in kN/m^2, to be considered for the bow impact design load scenario is to be taken as:

P_{FB}=1.025$f_{FB}c_{FB}V^2_{im}\sin\gamma wl$

where:

f_{FB} : Longitudinal bow flare impact pressure distribution factor. To be taken as:

f_{FB}=0.55 for $x/L \leqslant 0.9$

f_{FB}=4(x/L-0.9)+0.55 for 0.9< $x/L \leqslant 0.9875$

f_{FB}=8(x/L-0.9875)+0.9 for 0.9875< $x/L \leqslant 1.0$

f_{FB}=1.0 for x/L>1.0

V_{im} : Impact speed, in knots, to be taken as:

$$V_{im} = 0.514V_{ref}\sin\alpha_{wl} + \sqrt{L}$$

V_{ref} : Forward speed, in knots, to be taken as:

V_{ref} =0.75V, but not less than 10.

α_{wl} : Local waterline angle, in deg, at the considered position, but not less than 35 deg. See Figure 12.

γ_{wl} : Local bow impact angle, in deg, measured in a vertical plane containing the normal to the shell, from the horizontal to the tangent line at the considered position but not less than 50 deg, as shown in Figure 12. Where this value is not available, it may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

For ships with bow impact angle less than 50 deg, the impact pressure is to be individually considered by the Society. The resulting scantling individually considered by the Society is in no case to be less than the scantling calculated in accordance with [3.3.1] for local bow impact angle equal to 50 deg.

β_{pl} : Local body plan angle, in deg, at the considered position from the horizontal to the tangent line, but not less than 35 deg.

c_{FB} : Coefficient to be taken as:

c_{FB}=1.0 for positions between draughts T_{BAL} and T_{SC}

$$c_{FB} = \sqrt{1.0 + \cos^2\left[90\frac{(h_{fb} - 2h_0)}{h_{fb}}\right]}$$ for positions above draughts T_{SC}

h_{fb} : Vertical distance, in m, from the waterline at the draught T_{SC} to the highest deck at side. See Figure12.

h_0 : Vertical distance, in m, from the waterline at the draught T_{SC} to the considered position. See Figure 12.

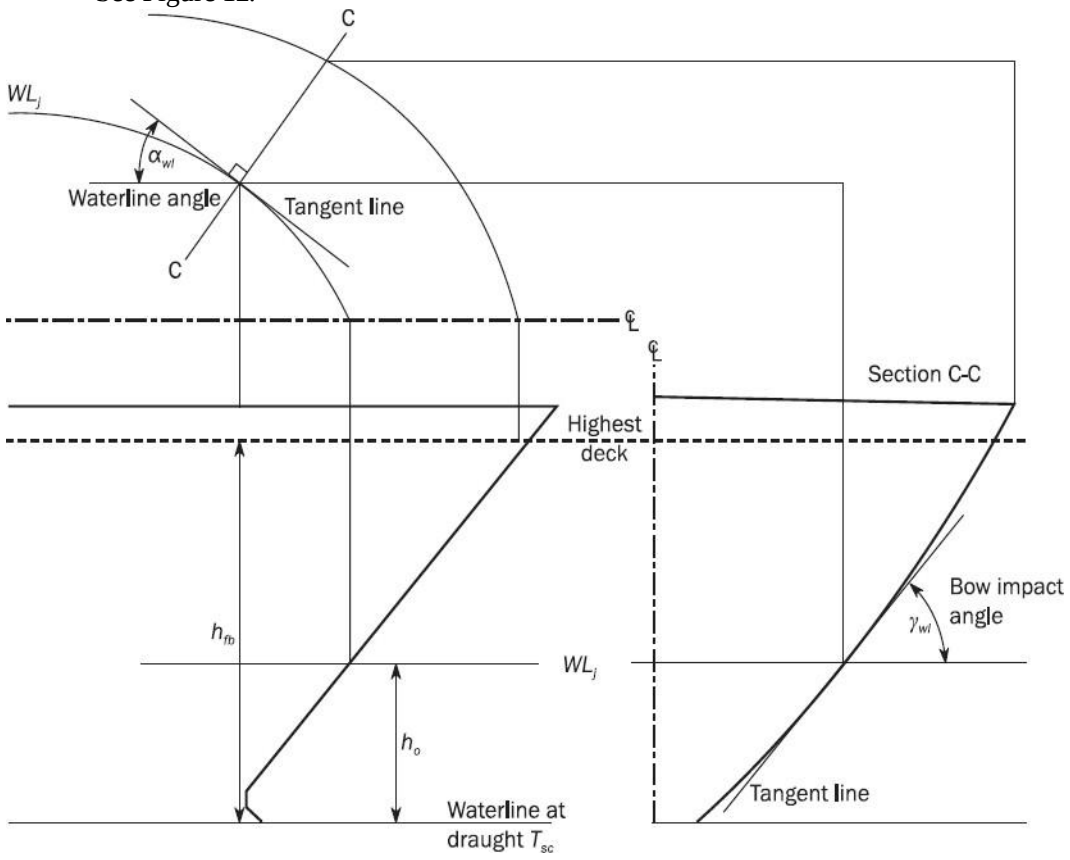


Figure 12 Definition of bow geometry

ISC 3.3.1a For ships with impact angle, γ_{wl}, less than 50 deg, in addition to [3.3.1], the requirements given in Ch 6, Sec 7, [3.3] of ISC Rules for Structures of Container Ships are to be complied also.

4 EXTERNAL PRESSURES ON SUPERSTRUCTURE AND DECKHOUSES

4.1 Application

4.1.1

The external pressures on superstructure and deckhouses are only to be applied for strength assessment. These pressures are to be considered as dynamic pressures and are to be applied to the appropriate structure without any static pressure load component.

4.1.2

The dynamic load case concept is not to be applied for external pressures on

superstructures and deckhouses.

4.2 Exposed wheel house tops

4.2.1

The lateral pressure for exposed wheel house tops, P_D, in kN/m^2, is to be taken as:

P_D=12.5

4.3 Sides of superstructures

4.3.1

The design pressure for the external sides of superstructures, P_{SI}, in kN/m^2, is to be taken as:

$$P_{SI} = 2.1 C_w c_F (C_B + 0.7) \frac{20}{10 + z_{SD} - T_{SC}}$$

where:

c_F : Distribution factor according to Table 32.

Distribution factor c_F **Table32**

Location	c_F
x/L < 0.2	$1.0 + \frac{5}{C_B}\left(0.2 - \frac{x}{L}\right)$ without taking x/L less than 0.1
$x/L \geqslant 0.2$	1.0

4.4 End bulkheads of superstructures and deckhouse walls

4.4.1

The external pressure for the aft and forward external bulkheads of superstructures and deckhouse walls, in kN/m^2, is to be taken as:

$P_A = f_n f_c [f_b f_d - (z_{SD} - T_{SC})]$

but is not to be less than $P_{A\text{-}min}$.

where:

f_n : Coefficient defined in Table 33.

f_c : Coefficient, to be taken as:

$$f_c = 0.3 + 0.7 \frac{b_1}{B_1}, \text{ but not less than } 0.475$$

For exposed parts of machinery casings, f_c is not to be taken less than 1.0.

f_d : Coefficient, to be taken as:

$$f_d = \frac{L}{10} e^{-(L/300)} - \left(1 - \left(\frac{L}{150}\right)^2\right) \text{ for } L < 150 \text{ m}$$

$$f_d = \frac{L}{10} e^{-(L/300)} \text{ for } 150 \text{ m} \leqslant L < 300 \text{ m}$$

f_d = 11.03 for $L \geqslant$ 300 m

b_1 : Breadth of deckhouse at the position considered.

B_1 : Actual breadth of ship on the exposed weather deck at the position considered.

f_b : Coefficient defined in Table 34.

$P_{A\text{-}min}$: Minimum lateral pressure, in kN/m^2, as defined in Table 35.

5 EXTERNAL PRESSURES ON HATCH COVERS

5.1 Application

5.1.1

The external pressures on hatch covers are only to be applied for strength assessment.

5.2 Green sea loads

5.2.1

The green sea loads at any load point of a hatch cover, *PHC*, in kN/mm2, is to be taken as follows:

- For cargo hold analysis according to Ch 7:
  $P_{HC} = P_D - \rho g (z_{HC} - D)$, without being less than 0

- For other cases: $P_{HC} = P_{D,min}$ as defined in Table 30.

P_D : Green sea pressure, in kN/mm^2, on the deck in way of the hatch cover obtained according to [2.2], considering χ equal to 1.0.

z_{HC} : z coordinate of the top of the hatch cover, in m.

5.3 Load carried on hatch covers

5.3.1

If a distributed load or a unit load is carried on a hatch cover, the pressure is to be obtained according to [2.3].

Coefficient f_n **Table33**

Type of bulkhead	Location	f_n
Unprotected front bulkhead (1)	Lowest tier (2)	$20+\frac{L_2}{12}$
	Second tier	$10+\frac{L_2}{12}$
	Third tier and above	$5+\frac{L_2}{15}$
Protected front bulkhead (1)	All tiers	$5+\frac{L_2}{15}$
Side bulkheads	All tiers	$5+\frac{L_2}{15}$
Aft end bulkheads	Abaft amidships	$7+\frac{L_2}{100}-8\frac{x}{L_2}$
	Forward of amidships	$5+\frac{L_2}{100}-4\frac{x}{L_2}$

(1) The front bulkhead of a superstructure or deckhouse may be considered as protected when it is located less than Bx behind another superstructure or deckhouse, and the width of the front bulkhead being considered is less than the width of the aft bulkhead of the superstructure or deckhouse forward of it. B_x is the local breadth of the ship at the front bulkhead.

(2) The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when (D - T_{SC}) exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 4, [3.3]), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

Coefficient f_b **Table 34**

Location of bulkhead (1)	f_b
$\frac{x}{L}<0.45$	$1.0+\left(\frac{x/L-0.45}{C_{B1}+0.2}\right)^2$
$\frac{x}{L}\geq 0.45$	$1.0+1.5\left(\frac{x/L-0.45}{C_{B1}+0.2}\right)^2$

where:

C_{B1} : Block coefficient, but not less than 0.60 nor greater than 0.80. For aft deckhouse bulkheads located forward of amidships, C_{B1} may be taken as 0.80.

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0.15L each, and x is to be taken as the X-coordinate of the centre of each part considered.

Minimum lateral pressure, $P_{A\text{-}min}$ **Table 35**

	$P_{A\text{-}min}$, kN/m^2	
L	Lowest tier of unprotected fronts	Elsewhere (1)
$90 < L \leq 250$	$25+\frac{L}{10}$	$12.5+\frac{L}{20}$
L>250	50	25

(1) For the 4th tier and above, $P_{A\text{-}min}$ is to be taken equal to 12.5 kN/m^2.

Section 6 INTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

a_X, a_Y, a_Z: Longitudinal, transverse and vertical accelerations, in m/s^2, at x_G, y_G, z_G, as defined in Ch 4, Sec 3, [3.2].

B_H : Breadth of the cargo hold, in m, measured at mid-length of the cargo hold and at the mid height between the top of hopper tank and the bottom of topside tank, see Figure 2.

B_{IB} : Breadth of inner bottom, in m, measured at mid-length of the cargo hold, see Figure 2.

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

d_{sc} : Diameter, in m, of a steel coil.

f_{cd} : Factor for joint probability of occurrence of liquid cargo density and maximum sea state in 25 years design life, to be taken as:

- For strength assessment with FE analysis of cargo tanks filled with liquid cargo:
  f_{cd} = 1.0 for ρ_L > 1.025 t/m^3.
  f_{cd} = 0.88 for ρ_L = 1.025t/m^3.
- For other cases:
  f_{cd} = 1.0.

f_{dc} : Dry cargo factor taken as:
f_{dc} = 1.0 for strength assessment,
f_{dc} = 0.5 for fatigue assessment.

f_β : Coefficient defined in Ch 4, Sec 4.

h_{air} : Height of air pipe or overflow pipe above the top of the tank, in m.

h_C : Height of bulk cargo, in m, from the inner bottom to the upper surface of bulk cargo, as defined in[2.3.1] or [2.3.2].

h_{DB} : Height, in m, of the double bottom at the centreline, measured at mid-length of the cargo hold, see Figure 2.

h_{HPL} :Vertical distance, in m, from the inner bottom at centreline to the upper intersection of hopper tank and side shell or inner side for double side bulk carriers, determined at mid length of the considered cargo hold, as shown in Figure 2.
h_{HPL} = 0 if there is no hopper tank.

h_{HPU} : Vertical distance, in m, from the inner bottom at centreline to the lower intersection of topside tank and side shell or inner side for double side bulk carriers, determined at mid length of the cargo hold at midship, as shown in Figure 2.

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom.

h_{max} : Maximum permissible filling level, in m, taken as:
For ballast tanks: maximum tank height,

- For cargo tanks with cargo density equal to ρ_L: maximum tank height
- For cargo tanks with heavy liquid cargo density equal to ρ_{part} associated with a partially filled cargo tank: hpart as defined in Ch 10, Sec 4, [1.2.1].

K_C : Coefficient taken equal to:

$K_C = \cos^2\alpha + (1-\sin\Psi)\sin^2\alpha$	for $\alpha \leqslant 90°$
$K_C = (1-\sin\Psi)\sin^2\alpha$	for $90° < \alpha \leqslant 120°$
$K_C = 0.75(1-\sin\Psi)[1-(\alpha-120)/(60-\Psi)]$	for $\alpha > 120°$ and $\alpha + \Psi < 180°$
$K_C = 0$	when $\alpha + \Psi \geqslant 180°$

$K_{C\text{-}f}$: Coefficient taken equal to:

$$K_{C-f} = \tan^2\left(45 - \frac{\Psi}{2}\right)$$

l : Distance, in m, between floors.

l_H : Length of the cargo hold, in m, at the centreline between the transverse bulkheads. This is to be measured to the mid-depth of the corrugated bulkhead(s) if fitted.

l_{lp} : Distance, in m, between outermost dunnage per EPP in the ship X direction, see Figure 11.

l_{st} : Length, in m, of a steel coil.

M : Mass, in t, of the bulk cargo being considered.

M_{Full} : Cargo mass, in t, in a cargo hold corresponding to the volume up to the top of the hatch

coaming with a density of the greater of M_H/V_{Full} or 1.0 t/m^3.

M_{Full}=1.0V_{Full} but not less than M_H.

M_H : Cargo mass, in t, in a cargo hold that corresponds to the homogeneously loaded condition at maximum draught with 50% consumables.

M_{HD} : Maximum allowable cargo mass, in t, in a cargo hold according to design loading conditions with specified holds empty at maximum draught with 50% consumables. and all ballast water tanks in cargo hold region empty.

$M_{sc\text{-}ib}$: Equivalent mass of a steel coil, in t, on inner bottom, as defined in [4.3.1]

$M_{sc\text{-}hs}$: Equivalent mass of a steel coil, in t, on hopper side, as defined in [4.3.2].

n_1 : Number of tiers of steel coils.

n_2 : Number of load points per EPP of the inner bottom, see [4.1.3].

n_3 : Number of dunnages supporting one row of steel coils.

P_{drop} : Overpressure, in kN/m^2, due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange. It is to be defined by the designer, but not to be less than 25 kN/m^2.

P_{PV} : Design vapour pressure, in kN/m^2, but not less than 25 kN/m^2.

perm : Permeability of cargo, to be taken as:

perm = 0.3 for iron ore, coal cargoes and cement.

perm = 0 for steel coils and steel packed products.

R : Vertical coordinate of the ship rotation centre, defined in Ch 4, Sec 3.

s_C : Spacing of corrugations, in m, as defined in Ch 3, Sec 6, [10.4.2].

T_θ : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

V_{Full} : Volume, in m^3, of cargo hold up to top of the hatch coaming, taken as:

$V_{Full} = V_H + V_{HC}$.

V_H :Volume, in m^3, of cargo hold up to level of the intersection of the main deck with the hatch coaming excluding the volume enclosed by hatch coaming, see Figure 2.

V_{HC} : Volume, in m^3, of the hatch coaming, from the level of the intersection of the main deck with the hatch side coaming to the top of the hatch coaming, determined for the cargo hold at midship, as shown in Figure 2.

V_{TS} : Total volume, in m^3, of the portion of the lower bulkhead stools within the cargo hold length l_H and inboard of the hopper tanks.

W : Mass, in t, of a steel coil.

x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

x_G, y_G, z_G: X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank or fully filled cargo hold, i.e. V_{Full}, considered with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2].

In case of partially filled cargo hold, x_G, y_G, z_G to be taken as follows:

x_G, y_G: Volumetric centre of gravity of the cargo hold.

$z_G = h_{DB} + h_{C\text{-}cl} / 2$

z_{top} : Z coordinate of the highest point of tank, excluding small hatchways, in m.

z_C : Height of the upper surface of the cargo above the baseline in way of the load point, in m, to be taken as:

$z_C = h_{DB} + h_C$

α : Angle, in deg, between panel considered and the horizontal plane. The angle is to be measured inward and upward from horizontal plane outside cargo hold, between 0 and 180 deg, as shown in Figure 1.

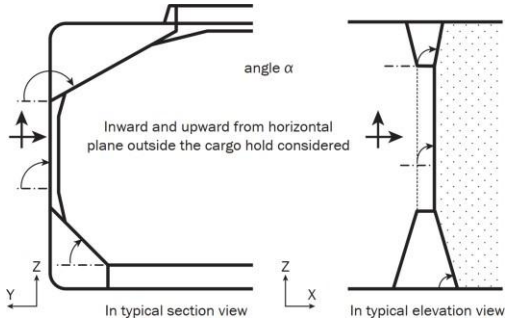


Figure 1 Measurement of angle α

φ : Pitch angle, in deg, defined in Ch 4, Sec 3, [2.1.2].

Ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); to be taken as:

Ψ= 30°in general.

Ψ= 35°for iron ore.

Ψ= 25°for cement.

ρ_C : Density of bulk cargo, in t/m^3, as defined in [2.3.3].

ρ_L : Density of liquid in the tank and ballast hold, in t/m^3, but not less than:

- For strength assessment:

ρ_L = 1.025 for all liquids including oil cargoes. If a tank filled at 98% is intended to carry heavier liquid cargoes than 1.025 (i.e. $\rho_{max\text{-}LM} > 1.025$), then $\rho_L = \rho_{max\text{-}LM}$.

- For fatigue assessment:

ρ_L = 0.9 for liquid cargoes.

ρ_L= 1.025 for all other liquids.

$\rho_{max\text{-}LM}$: Maximum liquid cargo density in t/m^3, associated with a full tank at 98%, from any loading condition in the ship's loading manual or value specified by the designer.

ρ_{part} : Maximum permissible high liquid cargo density, in t/m^3, associated with a partially filled cargo tank but not taken less than ρ_L considered for strength assessment.

ρ_{slh} : Liquid density, in t/m^3, to be used for sloshing assessment, taken as:

$\rho_{slh}=\rho_{part}$, for heavy liquid cargo density associated with partial filling of cargo

$\rho_{slh}=\rho_L$, for all other cases

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7.85.

Θ : Roll angle, in deg, defined in Ch 4, Sec 3, [2.1.1].

θ_h : Angle, in deg, between inner bottom plate and hopper sloping plate. in general θ_h is such that:

$$\tan\theta_h = \frac{2h_{HPL}}{B_H - B_{IB}}$$

1 PRESSURES DUE TO LIQUIDS

1.1 Application

1.1.1 Pressures for the strength and fatigue assessments of intact conditions

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in}=P_{ls}$ but not less than 0.

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$P_{in}=P_{ls}+P_{ld}$ but not less than 0.

where:

P_{ls} : Static pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.2].

P_{ld} : Dynamic inertial pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.3].

1.1.2 Pressures for the strength assessments of flooded conditions

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in}=P_{fs}$ but not less than $\rho g d_0$

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static plus dynamic (S+D) design load scenarios, is to be derived for each dynamic load case and is to be taken as:

$P_{in}=P_{fs}+P_{fd}$ but not less than $gd0$where:

P_{fs} : Static pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.4].

P_{fd} : Dynamic inertial pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.5].

d_0 : Distance, in m, to be taken as:

d_0=0.02L， form

d_0=2.4， for m

For corrugations of vertically corrugated bulkheads of bulk carrier cargo holds, the flooded pressures and forces specified in [3] for bulk cargoes are to be applied.

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure due to liquid in tanks and ballast holds, P_{ls} during normal operations at sea, in kN/m^2, is to be taken as:

$P_{ls}=f_{cd}\rho_L g(z_{top}-z)+P_{PV}$, for cargo tanks filled with liquid cargo.

$P_{ls}=\rho_L g(z_{top}-z+0.5h_{air})$, for other cases

1.2.2 Harbour/sheltered water operations

The static pressure, P_{ls} due to liquid in tanks and ballast holds for harbour/sheltered water operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z+h_{air})+P_{drop}$ for ballast tanks

$P_{ls}=\rho_L g(z_{top}-z)+P_{PV}$ for cargo tanks filled with liquid cargo

$P_{ls}=\rho_L g(z_{top}-z+0.5h_{air})$ for ballast holds with h_{air} = 0 and for other cases

1.2.3 Sequential ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with sequential ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho Lg(z_{top}-z+0.5h_{air})$

1.2.4 Flow through ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with flow through ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z+h_{air})+P_{drop}$

1.2.5 Ballasting using ballast water treatment system

The static pressure, P_{ls} due to liquid in tanks and ballast holds associated with ballasting operations using a ballast water treatment system is to be taken as defined for sequential ballast exchange in [1.2.3]. The ship designer has to inform the Society if the ballast water treatment system implies additional pressure to be considered as P_{drop}, etc in addition to the pressure defined in [1.2.3].

1.2.6 Static liquid pressure for the fatigue assessment

The static pressure due to liquid in tanks and ballast holds, P_{ls} to be used for the fatigue assessment, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z)$ for all tanks (cargo and water ballast tanks, ballast hold and other tanks).

1.3 Dynamic liquid pressure

1.3.1

The dynamic pressure, *Pld* due to liquid in tanks and ballast holds, in kN/m2 is to be taken as:

$P_{ld} = f_\beta f_{cd} \rho_L [a_Z (z_0 - z) + f_{ull\text{-}l}\, a_X (x_0 - x) + f_{ull\text{-}t}\, a_Y (y_0 - y)]$

where:

$f_{ull\text{-}l}$: Longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:
  $f_{ull\text{-}l}$ = 0.62 for cargo tanks filled with any liquids including water ballast.
  $f_{ull\text{-}l}$ = 1.0 for other cases.
- For fatigue assessment

$$f_{ull-l} = 0.5 + \frac{|z_0 - z|}{l_{fs}} \frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

f_{ull-l} = 1.0 for other cases.

f_{ull-l} is not to be less than 0.0 nor greater than 1.0

l_{fs} : Cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m.

f_{ull-t} : Transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:

  f_{ull-t} = 0.67 for cargo tanks filled with any liquids including water ballast.

  f_{ull-t} = 1.0 for other cases.

- For fatigue assessment

  $$f_{ull-t} = 0.5 + \frac{|z_0 - z|}{b_{top}} \frac{180}{\theta\pi}$$ for cargo tanks and ballast holds.

  f_{ull-t} = 1.0 for other cases.

  f_{ull-t} is not to be less than 0.0 nor greater than 1.0

b_{top} : Cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m, determined at mid length of the tank or ballast hold hatch coaming.

x_0 : X coordinate, in m, of the reference point.

y_0 : Y coordinate, in m, of the reference point.

z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j, calculated for all points that define the upper boundary of the tank or ballast hold as follows:

$V_j=a_X(x_j-x_G)+a_Y(y_j-y_G)+(a_z+g)(z_j-z_G)$

where:

x_j : X coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

y_j : Y coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

z_j : Z coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

1.4 Static pressure in flooded conditions

1.4.1 Static pressure in flooded compartments

The static pressure, P_{fs} in kN/m^2, for watertight boundaries of flooded compartments is to be taken as:

$P_{fs}=\rho g(z_{FD}-z)$ but not less than 0.

where:

z_{FD} : Z coordinate, in m, of the freeboard deck at side in way of the transverse section considered or the deepest equilibrium waterline in the damaged condition whichever is the greater.

1.5 Dynamic pressure in flooded conditions

1.5.1 Dynamic pressure in flooded compartments

The dynamic pressure, P_{fd}, in kN/m^2, for watertight boundaries of flooded compartments is to be taken as:

$P_{fd} = f_\beta \rho [a_Z (z_{0FD} - z) + f_{ull-l}\, a_X (x_0 - x) + f_{ull-t}\, a_Y (y_0 - y)]$

where:

z_{0FD} : Z coordinate of the effective reference point, in m, for a flooded compartment taken as:

When $z_{FD}>z_0$, $z_{0FD}=z_0$

When $z_{FD}\leqslant z_0$, $z_{0FD}=z_{FD}$

f_{ull-l}, f_{ull-t} : Longitudinal and transverse acceleration correction factors:

When $z_{FD}\leqslant z_0$, f_{ull-l} and f_{ull-t} are to be taken as defined in [1.3.1].

When $z_{FD}>z_0$, f_{ull-l} = 1.0 and f_{ull-t} = 1.0.

2 PRESSURES AND FORCES DUE TO DRY BULK CARGO

2.1 Application

2.1.1

The pressures and forces due to dry cargo in bulk in a cargo hold are to be determined both for fully and partially filled cargo holds according to [2.4] and [2.5].

2.2 Hold definitions

2.2.1 Geometrical characteristics

Figure 2 gives the main geometrical elements of a bulk carrier cargo hold.

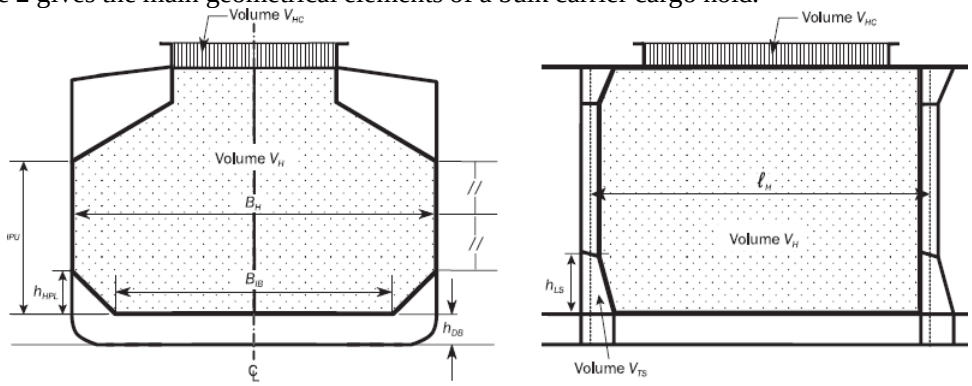


Figure 2 Definition of cargo hold parameters for bulk carrier

2.2.2 Fully and partially filled cargo holds

The definitions of a fully and partially filled dry bulk cargo holds are as follow:

a) Fully filled hold:
The dry bulk cargo density is such that the cargo hold is filled up to the top of the hatch coaming, as shown in Figure 3.
The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.1].

b) Partially filled hold:
The cargo density is such that the cargo hold is not filled up to the top of the hatch coaming, as shown in Figure 4 or Figure 5.
The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.2].

2.3 Dry cargo characteristics

2.3.1 Definition of the upper surface of dry bulk cargo for full cargo holds

For a fully filled cargo hold as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is an equivalent horizontal surface at h_C, in m, above inner bottom at centreline as shown in Figure 3.

The value of h_C is to be calculated at mid length of the cargo hold at the midship, is to be kept constant over the cargo hold region area and is determined as follows:

$h_C = h_{HPU} + h_0$

where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{l_H}$$

S_0: Shaded area, in m^2, above the lower intersection of topside tank and side shell or inner side, as the case may be, and up to the level of the intersection of the main deck with the hatch coaming, determined for the cargo hold at the midship as shown in Figure 3.

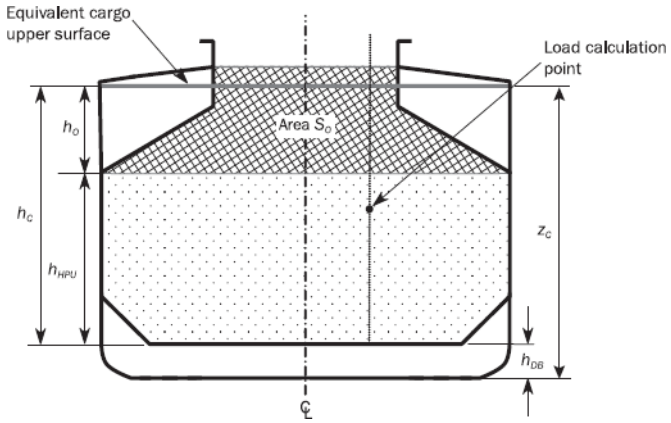


Figure 3 Definition of effective upper surface of cargo for a full cargo hold

2.3.2 Definition of upper surface of dry bulk cargo for partially filled cargo holds

For any partially filled cargo hold, as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is to be made of three parts:

- One central horizontal surface of breadth $B_H/2$, in m, at a height $h_{C\text{-}CL}$, in m, above the inner bottom
- A sloped surface at each side with an angle $\psi/2$, in degrees, between the central horizontal surface, and the side shell or inner hull, as shown in Figure 4, or the hopper plating, as shown in Figure 5, as the case may be.

The height of cargo surface h_C, in m, is to be calculated at mid length of the considered cargo hold and is to be taken as constant over the length of the hold as follows:

For $|y| \le \frac{B_H}{4}$: $h_C = h_{C_CL}$

For $\frac{B_H}{4} < |y| \le \frac{B_2}{2}$: $h_C = h_{C_CL} - \left(|y| - \frac{B_H}{2}\right)\tan\left(\frac{\varphi}{2}\right)$

For $|y| > \frac{B_2}{2}$: $h_C = 0$

where:

h_1 : Height, in m, to be taken as:

$$h_1 = \frac{M}{\rho c \cdot B_H l_H} - \left(\frac{B_H + B_{IB}}{2B_H}\right)h_{HPL} - \frac{3}{16}B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H l_H}$$

- For $h_1 \geqslant 0$ as shown in Figure 4:

  $h_{C_CL} = h_{HPL} + h_1 + h_2$

  $$h_2 = \frac{B_H}{4}\tan\frac{\psi}{2}$$

  $B_2 = B_H$

- For $h_1 < 0$ as shown in Figure 5

  $h_{C_CL} = h_{11} + h_{22}$

  $$h_{11} = h_{HPL}\left(\frac{B_2 - B_{IB}}{B_H - B_{IB}}\right)$$

  $$h_{22} = \left(\frac{B_2}{2} - \frac{B_H}{4}\right)\tan\frac{\psi}{2}$$

  $$B_2 = \sqrt{\frac{\frac{1}{l_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{1}{2}\left(\frac{h_{HPL} \cdot B_{IB}^2}{B_H - B_{IB}}\right) + \frac{B_H^2}{16}\tan\frac{\psi}{2}}{\frac{1}{2}\left[\left(\frac{h_{HPL}}{B_H - B_{IB}}\right) + \frac{1}{2}\tan\frac{\psi}{2}\right]}}$$

$h_{C\text{-}CL}$: Height, in m, of the cargo surface at the centreline, as shown in Figure 4 and Figure 5

B_2 : Maximum breadth of the cargo, in m, as shown in Figure 4 and Figure 5

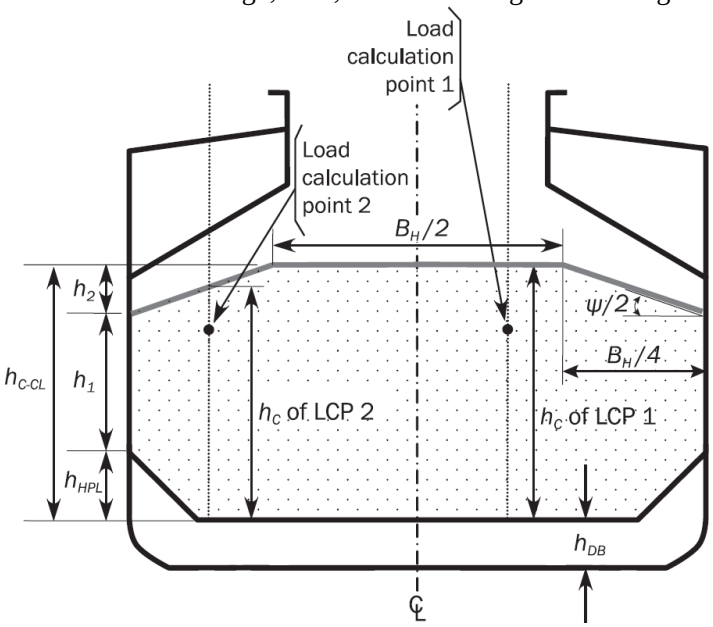


Figure 4 Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 \geqslant 0$

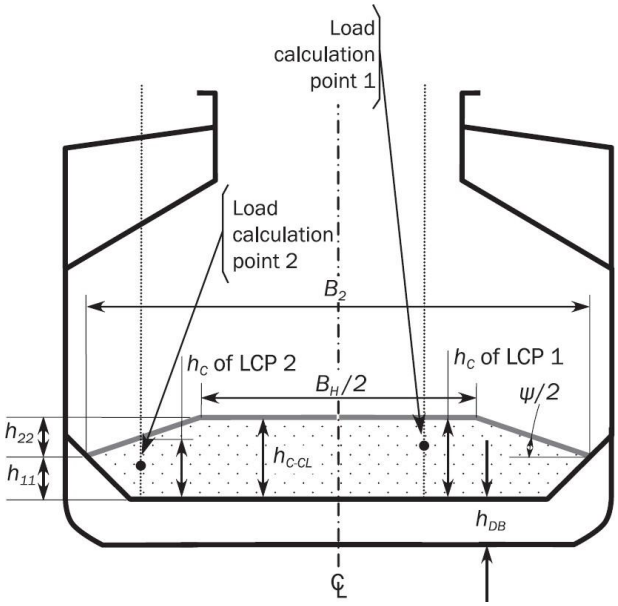


Figure 5 Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 < 0$

2.3.3 Mass and density

The dry cargo mass and the density of the cargo are to be taken as follows:

- For strength assessment in intact condition: the values defined in Table 1
- For fatigue assessment: the values defined in Table 2
- For strength assessment in flooded condition: the values defined in Table 3

Dry bulk cargo mass and density for strength assessment in intact condition Table1

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition	
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold
No BC notation	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	Maximum value specified in the loading manual			
BC-C	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than			
BC-B	M	$M = M_{Full}$	$M = M_H$	N/A	
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than	$\rho_C = 3.0$ (1)		
BC-A	M	$M = M_{Full}$	$M = M_H$	$M = M_{HD} + 0.1M_H$	$M = M_{HD} + 0.1M_H$
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than	$\rho_C = 3.0$ (1)	$\rho_C = \frac{M_{HD} + 0.1M_H}{V_{Full}}$	$\rho_C = 3.0$ (1)
(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.					

Dry bulk cargo mass and density for fatigue assessment Table 2

Ship type	Cargo mass Cargo density	Homogeneous loading condition (Fully filled hold)	Alternate loading condition (Partially filled hold)
No BC notation	M	$M = M_H$	N/A
	ρ_C	ρ_C = maximum value specified in the loading manual	
BC-C	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-B	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-A	M	$M = M_H$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)
(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.			

Dry bulk cargo mass and density for strength assessment in flooded condition Table 3

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition		
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold	Hold loaded with ρ_C=1.78 t/m^3 (2)
No BC notation	M	$M = M_H$		N/A		
	ρ_C	ρ_C = maximum value specified in the loading manual				
BC-C	M	$M = M_H$		N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$				
BC-B	M	$M = M_H$	$M = M_H$	N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)			
BC-A	M	$M = M_H$	$M = M_H$	$M = M_{HD}$	$M = M_{HD}$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)	$\rho_C = \left(\frac{M_{HD}}{V_{Full}}\right)$	ρ_C=3.0 (1)	$\rho_C = 1.78$

(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.
(2) To be applied for bulk carriers that are required to carry cargoes with a density less than or equal to 1.78 t/m^3.

2.3.4 FE application

The following process is to be applied for the bulk cargo pressure loads used in FE analysis:

a) Determine h_c according to [2.3.1] for fully filled cargo hold or [2.3.2] for partially filled cargo hold.

b) Determine the corresponding static pressure as defined in [2.4.2] and static shear pressure as defined in ρ_C [2.5.2] using and apply them in the FE model.

c) Calculate the actual mass of cargo, M_{actual}, in t.

d) Determine the effective cargo density, in t/m^3:

$$\rho_{eff} = \frac{M}{M_{actual}} \rho_C$$

e) Calculate the final pressure distribution and shear load using ρ_{eff} instead of ρ_C.

2.4 Dry bulk cargo pressures

2.4.1 Total pressure

The total pressure due to dry bulk cargo acting on any load point of a cargo hold boundary, in kN/m^2, is to be taken as:

$P_{in}=P_{bs}$ For strength assessment of intact conditions for static (S) design load scenarios, given in Ch 4, Sec 7

$P_{in}=P_{bs}+P_{bd}$ For strength assessment of intact conditions and fatigue assessment for static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7

but not less than 0.

where:

P_{bs} : Static pressure due to dry bulk cargo, in kN/m^2, as defined in [2.4.2].

P_{bd} : Dynamic inertial pressure due to dry bulk cargo in cargo holds, in kN/m^2, as defined in [2.4.3].

Static and dynamic pressures as defined in [2.4.2] and [2.4.3] for FE analysis are to be determined using ρ_{eff} instead of ρ_C.

2.4.2 Static pressure

The dry bulk cargo static pressure P_{bs}, in kN/m^2, is to be taken as:

$P_{bs}=\rho_C g K_C(z_C-z)$ but not less than 0.

2.4.3 Dynamic pressure

The dry bulk cargo dynamic pressure P_{bd}, in kN/m^2, for each load case is to be taken as:

$P_{bd}=f_\beta\rho_C[0.25a_X(x_G-x)+ 0.25a_Y(y_G-y)+f_{dc}K_Ca_Z(z_C-z)]$ for $z\leqslant z_C$

$P_{bd}=0.0$ for $z>z_C$

2.5 Shear load

2.5.1 Application

For FE strength assessment and FE fatigue assessment, the following shear load pressures are to be considered in addition to the dry bulk cargo pressures defined in [2.4] when the load point elevation, z, is lower or equal to z_c:

- For static (S) design load scenarios, given in Ch 4, Sec 7: Static shear load, $P_{bs\text{-}s}$, due to gravitational forces acting on hopper tanks and lower stools plating, as defined in [2.5.2].
- For static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7: The following dynamic shear load pressures:
  $P_{bs\text{-}s} + P_{bs\text{-}d}$ for the hopper tank and the lower stool plating, as defined in [2.5.3].
  $P_{bs\text{-}dx}$ for the inner bottom plating in the longitudinal direction, as defined in [2.5.4].
  $P_{bs\text{-}dy}$ for the inner bottom plating in the transverse direction, as defined in [2.5.4].

Shear loads as defined in [2.5.2] to [2.5.4] for FE analysis are to be determined using ρ_{eff} instead of ρ_c.

2.5.2 Static shear load on the hopper tank and lower stool plating

The static shear load pressure, $P_{bs\text{-}s}$ (positive downward to the plating) due to dry bulk cargo gravitational forces acting on hopper tank and lower stool plating, in kN/m^2, is to be taken as:

$$P_{bs-s} = \rho_C g \frac{(1-K_C)(z_C-z)}{\tan\alpha}$$

2.5.3 Dynamic shear load on the hopper tank and lower stool plating

The dynamic shear load pressure, $P_{bs\text{-}d}$ (positive downward to the plating) due to dry bulk cargo forces on the hopper tank and lower stool plating, in kN/m^2, for each dynamic load case is to be taken as:

$$P_{bs-d} = f_\beta \rho_C a_Z \frac{(1-K_C)(z_C-z)}{\tan\alpha}$$

2.5.4 Dynamic shear load along the inner bottom plating for FE analyses

The dynamic shear load pressures, $P_{bs\text{-}dx}$ in the longitudinal direction (positive to bow) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as:

$P_{bs\text{-}dx}= -0.75f_\beta\rho_Ca_Xh_C$

The dynamic shear load pressures, $P_{bs\text{-}dy}$ in the transverse direction (positive to port) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as

$P_{bs\text{-}dy}= -0.75f_\beta\rho_Ca_Yh_C$

The dynamic shear load pressures $P_{bs\text{-}dx}$ and $P_{bs\text{-}dy}$ are only used for FE strength assessment.

3 PRESSURES AND FORCES DUE TO DRY CARGOES IN FLOODED CONDITIONS

3.1 Vertically corrugated transverse watertight bulkheads

3.1.1 Application

The pressure defined in this sub-article applies to vertically corrugated transverse watertight bulkheads of the cargo holds of bulk carriers for the assessment in flooded conditions.

Each cargo hold is to be considered individually flooded, see Figure 6, Figure 7 and Figure 8.

3.1.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of loads induced by cargo loads with those induced by the flooded loads of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooded loads without cargo is also to be considered.

The most severe combinations of cargo induced loads and flooded loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual considering the individual flooded condition of both loaded and empty holds:

- Homogeneous loading conditions;
- Non-homogeneous loading conditions;

For the purpose of this article, the following items are defined as:

- Design load limits:
  The specified design load limits for the cargo holds are to be represented by loading conditions defined by the designer in the loading manual.
- Maximum cargo mass to consider:
  Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the top of the hatch coaming.
- Homogeneous loading conditions:
  Homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling level, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.
- Packed cargoes:
  Holds carrying packed cargoes (such as steel mill products) are to be considered as empty.
- Unconsidered loading conditions:
  Non-homogeneous part loading conditions associated with multi-port loading and unloading operations for homogeneous loading conditions do not need to be considered for the verification of these requirements.

3.1.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 4.

Flooded level z_F, in m, for vertically corrugated transverse bulkheads Table 4

Bulk carrier type	Loading Condition	Vertically corrugated transverse bulkhead position	
		Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type B freeboard	Non-homogeneous loading conditions with cargo density less than 1.78 t/m^3	$z_F=0.9D_1$	$z_F=0.8D_1$
	Other cases	$z_F = 0.95D_1$	$z_F = 0.85D_1$
Other bulk carriers	Non-homogeneous loading conditions with cargo density less than 1.78 t/m^3	$z_F=0.95D_1$	$z_F=0.85D_1$
	Other cases	$z_F =D_1$	$z_F=0.9D_1$

3.1.4 Flooded patterns

Three different flooded patterns are to be considered:

- The flooded level is below the upper surface of the cargo, (see Figure 6: $z_C > z_F$)
- The flooded level is above the upper surface of the cargo, (see Figure 7: $z_C \leqslant z_F$)
- The flooded hold is empty, (see Figure 8: $z_C = h_{DB}$)

3.1.5 Pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The static pressure $P_{bf\text{-}s}$, in kN/m^2, at any point of the vertically corrugated transverse bulkhead located at a level z from the baseline is given in Table 5 for each flooded pattern defined in [3.1.4]. The force $F_{bf\text{-}s}$, in kN, acting on a corrugation of a transverse bulkhead is given by Table 6 for each flooded pattern defined in [3.1.4].

where:

$P_{bf\text{-}s\text{-}LE}$: Static pressure calculated according to Table 5 for $z = h_{LS}+h_{DB}$

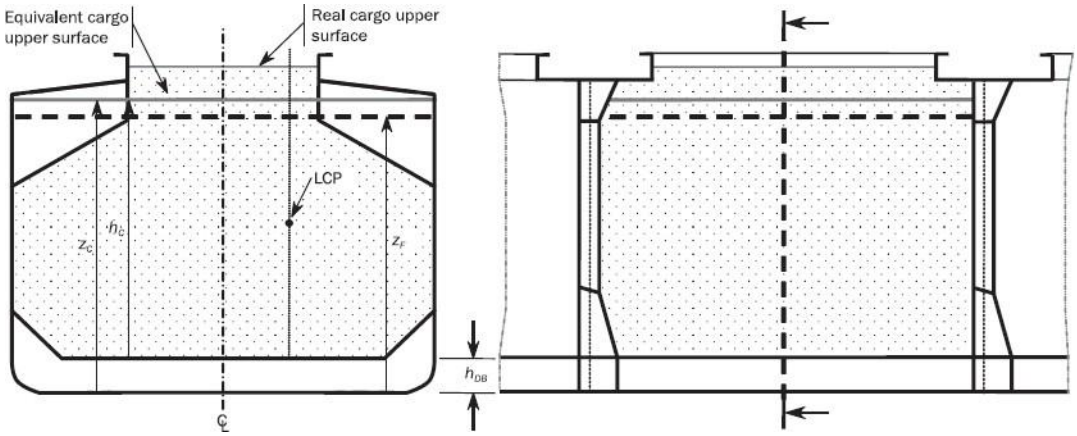


Figure 6 Flooded level below upper surface of bulk cargo

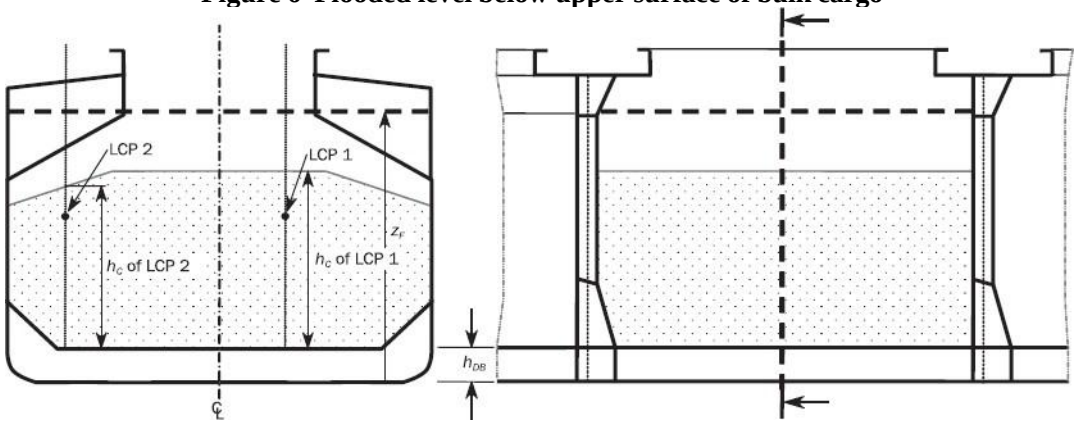


Figure 7 Flooded level above upper surface of bulk cargo

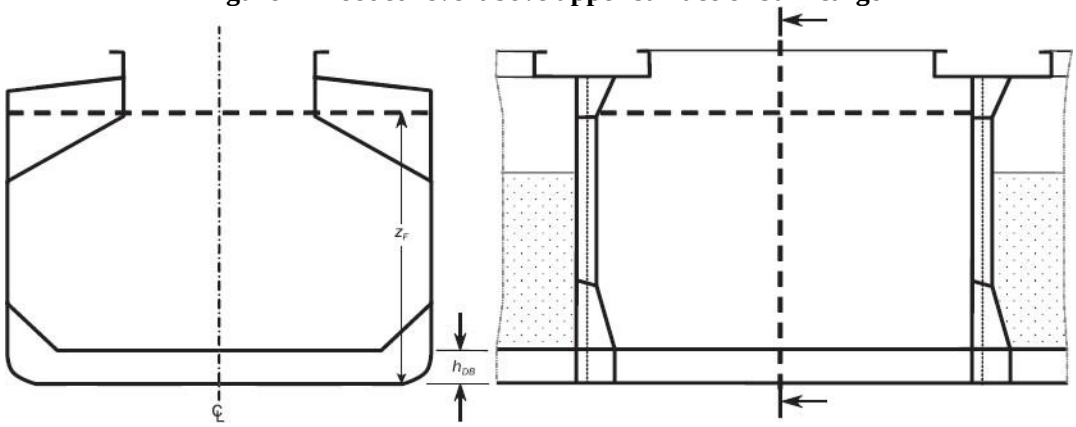


Figure 8 Flooded cargo hold without cargo

Static pressure on vertically corrugated transverse bulkhead of a flooded cargo hold $P_{bf\text{-}s}$

Table 5

Flooded case	Load point position	Pressure $p_{bf\text{-}s}$, in kN/m^2
$z_C > z_F$	$z > z_C$	$P_{bf\text{-}s}=0$
	$z_C \geqslant z \geqslant z_F$	$P_{bf\text{-}s}=\rho_C g(z_C-z)K_{C\text{-}f}$
	$z_F \geqslant z \geqslant h_{DB}$	$P_{bf\text{-}s}=\rho g(z_F-z)+[\rho_C(z_C-z)-\rho(1\text{-}perm)(z_F-z)]gK_{C\text{-}f}$
$h_{db} \leqslant z_C \leqslant z_F$	$z > z_F$	$P_{bf\text{-}s}=0$
	$z_F \geqslant z \geqslant z_C$	$P_{bf-s}=g(z_F-z)$
	$z_C \geqslant z \geqslant h_{DB}$	$P_{bf\text{-}s}=\rho g(z_F-z)+[\rho_C-\rho(1\text{-}perm)]g(z_C-z)K_{C\text{-}f}$

Force acting on a corrugation in the flooded cargo holds F_{bf-s} **Table 6**

Flooded case	Force F_{bf-s}, in kN
$z_C > z_F$	$F_{bf-s} = s_C \left\{ \rho_C g \frac{(z_C - z_F)^2}{2} K_{C-f} + \left[\frac{\rho_C g (z_C - z_F) K_{C-f} + p_{bf-s-LE}}{2} \right] (z_F - h_{DB} - h_{LS}) \right\}$
$z_F \geqslant z_C$	$F_{bf-s} = s_C \left\{ \rho g \frac{(z_C - z_F)^2}{2} + \left[\frac{\rho g (z_F - z_C) + p_{bf-s-LE}}{2} \right] (z_C - h_{DB} - h_{LS}) \right\}$

3.1.6 Pressures and forces on vertically corrugated transverse bulkheads of non-flooded cargo holds

The static pressure P_{bs}, in kN/m^2, at a point of the vertically corrugated transverse bulkhead located, located at the level z from the baseline, due to dry bulk cargo of a non-flooded cargo hold acting on the intact side of the transverse bulkhead which is flooded on the other side is to be taken as:
$P_{bs}=\rho_C g K_{C-f}(z_C - z)$, but not less than 0.
The resultant force F_{bs}, in kN, acting on a corrugation is to be taken as:

$$F_{bs} = \rho_C g s_C \frac{(z_C - h_{DB} - h_{LS})^2}{2} K_C$$

3.1.7 Resultant pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The resultant pressure P_R, in kN/m^2, at each point of the bulkhead, and the resultant force F_R, in kN, acting on a corrugation, given in Table 7, are to be considered for the assessment in flooded conditions of vertically corrugated transverse bulkhead structures, where:
P_{bf-s}: Pressure in the flooded cargo holds, in kN/m^2, as defined in [3.1.5].
P_{bs}: Pressure in the non-flooded cargo holds, in kN/m^2, as defined in [3.1.6].
F_{bf-s} : Force acting on a corrugation in the flooded cargo holds, in kN, as defined in [3.1.5].
F_{bs} : Force acting on a corrugation in the non-flooded cargo holds, in kN, as defined in [3.1.6].

Resultant pressure P_R and resultant force F_R on vertically corrugated transverse bulkhead in flooded condition **Table 7**

Loading condition	Resultant pressure P_R, in kN/m^2	Resultant force F_R, in kN	Application
Homogeneous	$P_R = P_{bf-s} - 0.8\, P_{bs}$	$F_R = F_{bf-s} - 0.8\, F_{bs}$	All bulk carriers
Alternate	$P_R = P_{bf-s}$	$F_R = F_{bf-s}$	BC-A bulk carriers

3.2 Double bottom in cargo hold region of bulk carrier in flooded conditions

3.2.1 Application

Each cargo hold is to be considered individually flooded.

3.2.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold to which the double bottom belongs.
The most severe combinations of cargo induced loads and flooded loads are to be used, depending on the loading conditions included in the loading manual:

- Homogeneous loading conditions.
- Non-homogeneous loading conditions.
- Packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.2.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 8.

Flooded level z_F, for double bottom in cargo hold region of bulk carrier Table 8

Bulk carrier type	Cargo hold	
	Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type-B freeboard	$z_F = 0.95\ D_1$	$z_F = 0.85\ D_1$
Other bulk carriers	$z_F = D_1$	$z_F = 0.9\ D_1$

4 STEEL COIL LOADS IN CARGO HOLDS OF BULK CARRIERS

4.1 General

4.1.1 Application

The provision is determined by assuming Figure 9 as the standard means of securing steel coils loaded on wooden dunnage.

It is assumed that all the steel coils have the same characteristics.

In cases where steel coils are lined up in two or more tiers, formulae in [4.1.3] and [4.2] can be applied assuming that only the lowest tier of steel coils is in contact with hopper sloping plate or inner side plate. In other cases, scantling requirements are to be determined on a case-by-case basis.

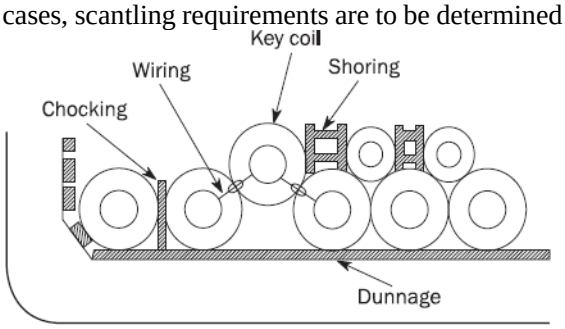


Figure 9 Inner bottom loaded by steel coils

4.1.2 Arrangement of steel coils on inner bottom

The two following arrangements of steel coils on the inner bottom are considered:

- The steel coils are positioned without respect to the location of the inner bottom floors, as shown in Figure 10.
- The steel coils are positioned with respect to the location of the inner bottom floors, as shown in Figure 11.

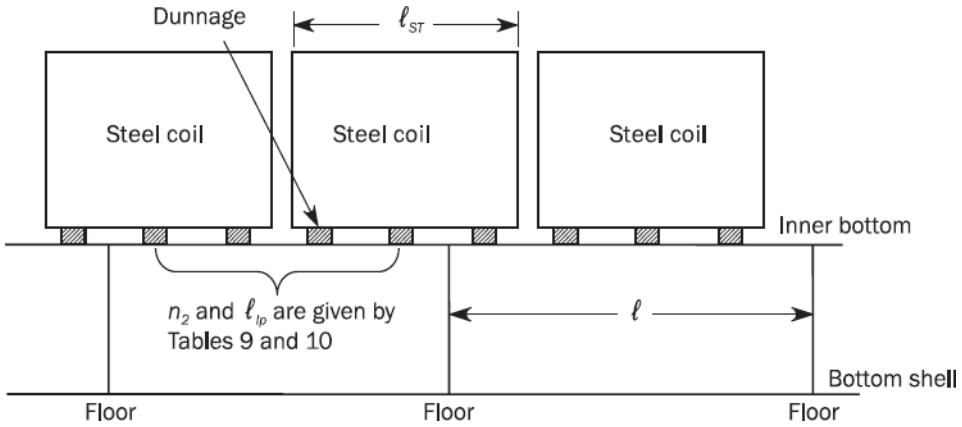


Figure 10 Steel coils loaded independently of inner bottom floors locations

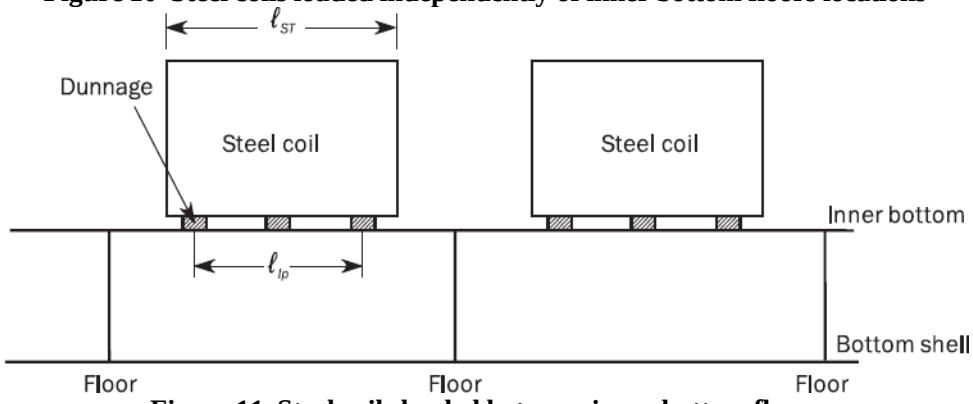


Figure 11 Steel coils loaded between inner bottom floors

4.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Figure 10:
The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Table 9.
The distance l_{lp}, in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Table 10.

Number n_2 of load point dunnages per elementary plate panel **Table 9**

n_2 (1) (2)	n_3 (3)				
	2	3	4	5	6
1	$0 < \frac{l}{l_{st}} \le 0.5$	$0 < \frac{l}{l_{st}} \le 0.33$	$0 < \frac{l}{l_{st}} \le 0.25$	$0 < \frac{l}{l_{st}} \le 0.2$	$0 < \frac{l}{l_{st}} \le 0.17$
2	$0.5 < \frac{l}{l_{st}} \le 1.2$	$0.33 < \frac{l}{l_{st}} \le 0.67$	$0.25 < \frac{l}{l_{st}} \le 0.5$	$0.2 < \frac{l}{l_{st}} \le 0.4$	$0.17 < \frac{l}{l_{st}} \le 0.33$
3	$1.2 < \frac{l}{l_{st}} \le 1.7$	$0.67 < \frac{l}{l_{st}} \le 1.2$	$0.5 < \frac{l}{l_{st}} \le 0.75$	$0.4 < \frac{l}{l_{st}} \le 0.6$	$0.33 < \frac{l}{l_{st}} \le 0.5$
4	$1.7 < \frac{l}{l_{st}} \le 2.4$	$1.2 < \frac{l}{l_{st}} \le 1.53$	$0.75 < \frac{l}{l_{st}} \le 1.2$	$0.6 < \frac{l}{l_{st}} \le 0.8$	$0.5 < \frac{l}{l_{st}} \le 0.67$
5	$2.4 < \frac{l}{l_{st}} \le 2.9$	$1.53 < \frac{l}{l_{st}} \le 1.87$	$1.2 < \frac{l}{l_{st}} \le 1.45$	$0.8 < \frac{l}{l_{st}} \le 1.2$	$0.67 < \frac{l}{l_{st}} \le 0.83$
6	$2.9 < \frac{l}{l_{st}} \le 3.6$	$1.87 < \frac{l}{l_{st}} \le 2.4$	$1.45 < \frac{l}{l_{st}} \le 1.7$	$1.2 < \frac{l}{l_{st}} \le 1.4$	$0.83 < \frac{l}{l_{st}} \le 1.2$
7	$3.6 < \frac{l}{l_{st}} \le 4.1$	$2.4 < \frac{l}{l_{st}} \le 2.73$	$1.7 < \frac{l}{l_{st}} \le 1.95$	$1.4 < \frac{l}{l_{st}} \le 1.6$	$1.2 < \frac{l}{l_{st}} \le 1.37$
8	$4.1 < \frac{l}{l_{st}} \le 4.8$	$2.73 < \frac{l}{l_{st}} \le 3.07$	$1.95 < \frac{l}{l_{st}} \le 2.4$	$1.6 < \frac{l}{l_{st}} \le 1.8$	$1.37 < \frac{l}{l_{st}} \le 1.53$

n_2 (1) (2)	n_3 (3)				
	2	3	4	5	6
9	$4.8 < \frac{l}{l_{st}} \le 5.3$	$3.07 < \frac{l}{l_{st}} \le 3.6$	$2.4 < \frac{l}{l_{st}} \le 2.65$	$1.8 < \frac{l}{l_{st}} \le 2.0$	$1.53 < \frac{l}{l_{st}} \le 1.7$
10	$5.3 < \frac{l}{l_{st}} \le 6.0$	$3.6 < \frac{l}{l_{st}} \le 3.93$	$2.65 < \frac{l}{l_{st}} \le 2.9$	$2.0 < \frac{l}{l_{st}} \le 2.4$	$1.7 < \frac{l}{l_{st}} \le 1.87$

(1) In case l/l_{st} is greater than the value given in Table 9, n_2 is to be considered as greater than 10.
(2) For plating, n_2 is to be based on l. For stiffener, n_2 is to be derived with l replaced by l_{bdg}.
(3) The number of dunnages, n_3, considered at the design stage is to reflect the intended operation conditions. Unusual arrangements with 5 or more dunnages per row of steel coil need to be carefully considered by the designer and ship owner.

Distance between outermost load point dunnages per elementary plate panel, l_{lp}, in m

Table 10

n_2 (1)	n_3				
	2	3	4	5	6
1	Actual breadth of dunnages				
2	0.5 l_{st}	0.33 l_{st}	0.25 l_{st}	0.2 l_{st}	0.17 l_{st}
3	1.2 l_{st}	0.67 l_{st}	0.50 l_{st}	0.4 l_{st}	0.33 l_{st}
4	1.7 l_{st}	1.20 l_{st}	0.75 l_{st}	0.6 l_{st}	0.5 l_{st}
5	2.4 l_{st}	1.53 l_{st}	1.20 l_{st}	0.8 l_{st}	0.67 l_{st}
6	2.9 l_{st}	1.87 l_{st}	1.45 l_{st}	1.2 l_{st}	0.83 l_{st}
7	3.6 l_{st}	2.40 l_{st}	1.70 l_{st}	1.4 l_{st}	1.2 l_{st}
8	4.1 l_{st}	2.73 l_{st}	1.95 l_{st}	1.6 l_{st}	1.37 l_{st}
9	4.8 l_{st}	3.07 l_{st}	2.40 l_{st}	1.8 l_{st}	1.53 l_{st}
10	5.3 l_{st}	3.60 l_{st}	2.65 l_{st}	2.0 l_{st}	1.7 l_{st}

(1) When $n_2 > 10$, l_{lp} is to be taken equal to l.

4.1.4 Arrangement of steel coils between floors

For steel coils loaded with respect to the locations of floors in the inner bottom, see Figure 11:

- The number n_2 of load point dunnages per elementary plate panels is to be taken as: $n_2 = n_3$
- The distance l_{lp} between outermost load point dunnages per elementary plate panel is to be taken as the distance between the outermost dunnage supporting one row of steel coils.

4.1.5 Centre of gravity of steel coil cargo

The centre of gravity of the steel coil cargo of the considered cargo hold is to be taken at the following position:

a) Longitudinal position
x_{Gsc} is the X coordinate, in m, of the volumetric centre of gravity of the considered cargo hold with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

b) Transverse position

$$y_{Gsc} = \varepsilon \frac{B_H}{4}$$

c) Vertical position

$$z_{Gsc} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{sc}}{2}$$

where:

ε : Coefficient to be taken as:

ε=1.0 when a port side structural member is assessed.

ε= -1.0 when a starboard side structural member is assessed.

4.2 Total loads

4.2.1 Total load on the inner bottom

The total load $F_{sc\text{-}ib}$, in kN, due to steel coil cargoes on the inner bottom is to be taken as:

$F_{sc\text{-}ib}$=cos ($C_{XG}\cdot\varphi$) ·cos ($C_{YG}\cdot\theta$) ·$F_{sc\text{-}ib\text{-}s}$ + $F_{sc\text{-}ib\text{-}d}$, but not less than 0

where:

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, on the inner bottom, given in [4.3.1].

$F_{sc\text{-}ib\text{-}d}$: Dynamic load, in kN, on the inner bottom, given in [4.4.2].

C_{XG}, C_{YG}: Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.2.2 Total load on the hopper side

The total load $F_{sc\text{-}hs}$, in kN, due to steel coil cargoes on the hopper side is to be taken as:

$$F_{sc-ib} = \frac{\cos(C_{XG}\cdot\varphi)\cdot\cos(C_{YG}\cdot\theta)}{\cos\theta_h}\cdot F_{sc-hs-s} + F_{sc-hs-d} \text{ but not less than 0}$$

where:

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, on the hopper side, given in [4.3.2].

$F_{sc\text{-}hs\text{-}d}$: Dynamic load, in kN, on the hopper, given in [4.4.3].

C_{XG}, C_{YG}: Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.3 Static loads

4.3.1 Static loads on the inner bottom

The static load $F_{sc\text{-}ib\text{-}s}$, in kN, on the inner bottom due to steel coils is to be taken as:

$F_{sc\text{-}ib\text{-}s} = M_{sc\text{-}ib}\cdot g$

where:

$M_{sc\text{-}ib}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S W \frac{n_1 n_2}{n_3} \quad \text{for } n_2 \leqslant 10$$

$$M_{sc-ib} = K_S W n_1 \frac{l}{l_{st}} \quad \text{for } n_2 > 10, \text{ for plating}$$

$$M_{sc-ib} = K_S W n_1 \frac{l_{bdg}}{l_{st}} \quad \text{for } n_2 > 10, \text{ for stiffener}$$

K_S : Coefficient to be taken as:

K_S = 1.4 when steel coils are lined up in one tier with a key coil.

K_S = 1.0 in other cases.

4.3.2 Static load on the hopper side

The static load $F_{sc\text{-}hs\text{-}s}$, in kN, on the hopper side due to steel coils is to be taken as:

$F_{sc\text{-}hs\text{-}s}$=cos$\theta_h$ $M_{sc\text{-}hs}\cdot g$

where:

$M_{sc\text{-}hs}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k W \frac{n_2}{n_3} \quad \text{for } n_2 \leqslant 10$$

$$M_{sc-hs} = C_k W \frac{l}{l_{st}} \qquad \text{for } n_2>10, \text{ for plating}$$

$$M_{sc-hs} = C_K W \frac{l_{bdg}}{l_{st}} \qquad \text{for } n_2>10, \text{ for stiffener}$$

C_k : Coefficient to be taken as:

C_k = 3.2 when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate.

C_k = 2.0 for other cases.

4.4 Dynamic loads

4.4.1 Tangential roll acceleration

The tangential roll acceleration a_R, in m/s^2, is to be taken as:

$$a_R = \theta \cdot \frac{\pi}{180} \cdot \left(\frac{2\pi}{T_\theta}\right)^2 \cdot \sqrt{y_{Gsc}^2 + (R - z_{Gsc})^2}$$

where:

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.2 Dynamic load on the inner bottom

The dynamic load $F_{sc\text{-}ib\text{-}d}$, in kN, on the inner bottom due to steel coils is to be taken as:

$F_{sc\text{-}ib\text{-}d} = M_{sc\text{-}ib} \cdot a_z$

where:

a_z : Vertical acceleration, in m/s^2, as defined in Ch 4, Sec 3, [3.2.4], calculated at the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.3 Dynamic load on the hopper side

The dynamic load $F_{sc\text{-}hs\text{-}d}$, in kN, on the hopper side due to steel coils is to be taken as:

$$F_{sc-hs-d} = \varepsilon M_{sc-hs} \left[C_{YR} a_R \sin\left(\tan^{-1} \left| \frac{y_{Gsc}}{R - z_{Gsc}} \right| - \theta_h \right) - C_{YS} a_{sway} \sin\theta_h \right]$$

where:

C_{YS}, C_{YR} : Load combination factors, defined in Ch 4, Sec 2, [2.2].

a_{sway} : Sway acceleration, in m/s^2, as defined in Ch 4, Sec 3, [2.2.2].

a_R : Tangential acceleration, in m/s^2, as defined in [4.4.1].

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

5 LOADS ON NON-EXPOSED DECKS AND PLATFORMS

5.1 Application

5.1.1 General

The loads defined in [5.2] and [5.3] are applicable to non-exposed decks, accommodation decks and platforms.

5.2 Pressure due to distributed load

5.2.1

If a distributed load is carried on a deck, the static and dynamic pressures due to this distributed load are to be considered.

The static distributed load is to be defined by the designer without being less than 3kN/m^2 for accommodation decks and 10kN/m^2 for other decks and platforms.

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenarios,

given in Ch 4, Sec 7, is to be taken as:
$P_{dl}=P_{dl-s}$
The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:
$P_{dl}=P_{dl-s}+P_{dl-d}$ but not less than 0.
where:
P_{dl-s} : Static pressure, in kN/m^2, due to the distributed load.
P_{dl-d} : Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_{Z-env}}{g} P_{dl-s}$$

$a_{z\text{-}env}$: Envelope of vertical acceleration, in m/s^2, at the load position being considered, for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

5.3 Concentrated force due to unit load

5.3.1

If a unit load is carried on an internal deck, the static and dynamic forces due to the unit load carried are to be considered when a direct analysis is applied for stiffeners or primary supporting members such as in Pt 1, Ch6, Sec 5, [1.2] or Pt 1, Ch 6, Sec 6, [3.3] respectively.
The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:
$F_U=F_{U-s}$
The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:
$F_U=F_{U-s}+F_{U-d}$ but not less than 0.
where:
F_{U-s} : Static force, in kN, due to the unit load to be taken as:

$$F_{U-s} = m_U g$$

F_{U-d} : Dynamic force, in kN, due to unit load to be taken as:

$$F_{U-d} = m_U f_\beta a_{z-env}$$

m_U : Mass of the unit load carried, in t.
$a_{z\text{-}env}$: Envelope of vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

6 SLOSHING PRESSURES IN TANKS

6.1 General

6.1.1 Application

This article applies to all liquid cargo, ballast tanks and other tanks with volume exceeding 100 m^3, but does not apply to the water ballast cargo hold of bulk carriers.

6.1.2

The sloshing pressures defined in this article do not include the effect of impact pressures due to high velocity impacts with tank boundaries or internal structures. For tanks with a maximum effective sloshing breadth, b_{slh}, see [6.4.2], greater than 0.56B or a maximum effective sloshing length, l_{slh}, see [6.3.2], greater than 0.13L at any filling level from 0.05h_{max} to 0.95h_{max}, see [6.3.3], a separate impact assessment is to be carried out in accordance with the Society procedures.

ISC 6.1.2a Where $l_s>0.13L$ or $b_s>0.56B$ for the tank, level 3 sloshing impact loads are to be calculated in accordance with relevant requirements of Section 2 of ISC Guidelines for Assessment of Sloshing Loads and Structural Scantlings of Tanks.

6.1.3 Sloshing pressure on tank boundaries and internal divisions

The sloshing pressure due to liquid motions in a tank P_{slh} acting on any load point of a tank boundary or internal divisions, in kN/m^2, for the sloshing design load scenario, given in Ch4, Sec 7, is to be taken as follows, without being less than $P_{slh-min}$, as given in [6.2]:

- $P_{slh} = P_{slh-lng}$ for transverse bulkheads, as defined in [6.3.3].
- $P_{slh} = P_{slh-wf}$ for web frames and transverse stringers, as defined in [6.3.4].
- $P_{slh} = P_{slh-t}$ for longitudinal bulkheads, as defined in [6.4.3].

- $P_{slh} = P_{slh\text{-}grd}$ for longitudinal girders and stringers, see [6.4.4].

6.2 Minimum sloshing pressure

6.2.1

The minimum sloshing pressure, $P_{slh\text{-}min}$, for tanks of cellular construction, i.e. double hull construction with internal structures restricting the fluid motion, is to be taken as 12 kN/m^2.

The minimum sloshing pressure, $P_{slh\text{-}min}$, for cargo and all other tanks is to be taken as 20 kN/m^2.

6.3 Sloshing pressure due to longitudinal liquid motion

6.3.1 Application

The sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95h_{max}, in 0.05h_{max} increments.

6.3.2 Effective sloshing length

The effective sloshing length, l_{slh}, in m, is to be taken as defined in Table11.

Effective sloshing length l_{slh} **Table 11**

Type of transverse bulkhead	l_{zlh}
Transverse tight bulkheads	$l_{zlh} = \frac{(1+n_{WT}\alpha_{WT})(1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{WT})(1+f_{wf})}$
Transverse wash bulkheads	$l_{zlh} = \frac{[1+(n_{WT}-1)\alpha_{WT}](1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{WT})(1+f_{wf})}$

where:

n_{WT} : Number of transverse wash bulkheads in the tank.

α_{WT} : Transverse wash bulkhead coefficient, to be taken as (see Figure 12):

$$\alpha_{WT} = \frac{A_{OWT}}{A_{tk-t-h}}$$

For tanks with changing shape along the length and/or with wash bulkhead of different shape the transverse wash bulkhead coefficient, α_{WT}, may be taken as the weighted average of all wash bulkhead locations in the tank given as:

$$\alpha_{WT} = \frac{\sum_{i=1}^{n_{WT}} \frac{A_{OWT_i}}{A_{tk-t-h_i}}}{n_{WT}}$$

α_{wf} : Transverse web frame coefficient, to be taken as (see Figure 13):

$$\alpha_{wf} = \frac{A_{O-wf-h}}{A_{tk-t-h}}$$

For tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, α_{wf}, may be taken as the weighted average of all web frame locations in the tank given as:

$$\alpha_{wf} = \frac{\sum_{i=1}^{n_{wf}} \frac{A_{o-wf-h_i}}{A_{tk-t-h_i}}}{n_{wf}}$$

A_{OWT} : Total area of openings, in m^2, in the transverse section in way of the wash bulkhead below the considered filling height.

A_{tk-t-h} : Total transverse cross sectional area, in m^2, of the tank below the considered filling height.

A_{O-wf-h} : Total area of openings, in m^2, in the transverse section in way of the web frame below the considered filling height.

f_{wf} : Factor to account for number of transverse web frames and transverse wash bulkheads in the tank, to be taken as:

$$f_{wf} = \frac{n_{wf}}{1+n_{WT}}$$

n_{wf} : Number of transverse web frames, excluding wash bulkheads, in the tank.

l_{tk-h} : Length of cargo tank, in m, at considered filling height.

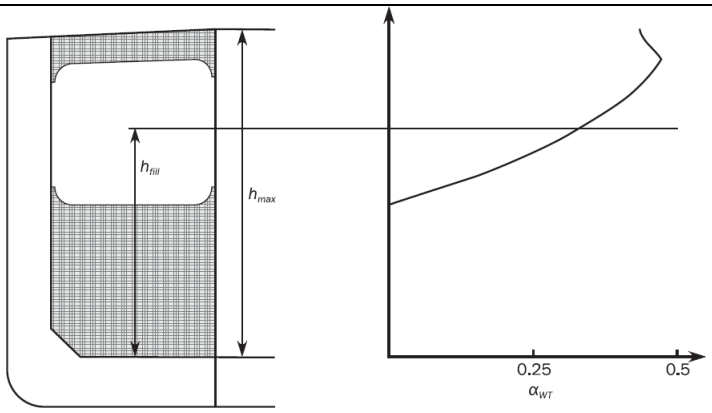


Figure 12 Transverse wash bulkhead coefficient

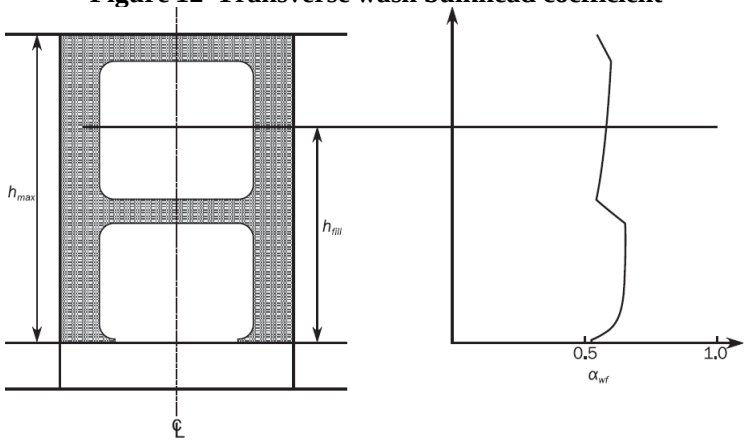


Figure 13 Transverse web frame coefficient

6.3.3 Sloshing pressure in way of transverse bulkheads

The sloshing pressure in way of transverse bulkheads including wash bulkheads due to longitudinal liquid motion, $P_{slh\text{-}lng}$, in kN/m^2, for a particular filling level, is to be taken as:

$$P_{slh-lng} = \rho_{slh} g l_{slh} \left[0.4 - \left(0.39 - \frac{1.7 l_{slh}}{L} \right) \frac{L}{350} \right]$$

where:

l_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

f_{slh} : Coefficient taken as:

$$f_{slh} = 1 - 2\left(0.7 - \frac{h_{fill}}{h_{max}} \right)^2$$

h_{fill} : Filling height, measured from tank bottom, in m, see Figure 12.

6.3.4 Sloshing pressure on internal web frames or transverse stringers adjacent to a transverse bulkhead

For tanks with internal web frames the sloshing pressure acting on a web frame or transverse stringer adjacent to transverse bulkheads or transverse wash bulkheads due to longitudinal liquid motion, $P_{slh\text{-}wf}$, in kN/m^2, provided it is located within $0.25 l_{slh}$ from the bulkhead, is to be taken as:

$$P_{slh-wf} = P_{slh-lng} \left(1 - \frac{s_{wf}}{l_{slh}} \right)^2$$

where:

l_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

$P_{slh\text{-}lng}$: Sloshing pressure due to longitudinal liquid motion acting on transverse bulkhead, as defined in [6.3.3].

s_{wf} : Distance from transverse bulkhead to web frame under consideration, in m.

The distribution of pressure across web frames and transverse stringers is given in Figure 14.

6.4 Sloshing pressure due to transverse liquid motion

6.4.1 Application

The sloshing pressure due to transverse liquid motion, *Pslh-t*, is to be taken constant as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95h_{max}, in 0.05h_{max} increments.

6.4.2 Effective sloshing breadth

The effective sloshing breadth, b_{slh}, in m, is to be taken as in Table 12, but not less than 0.3*B*.

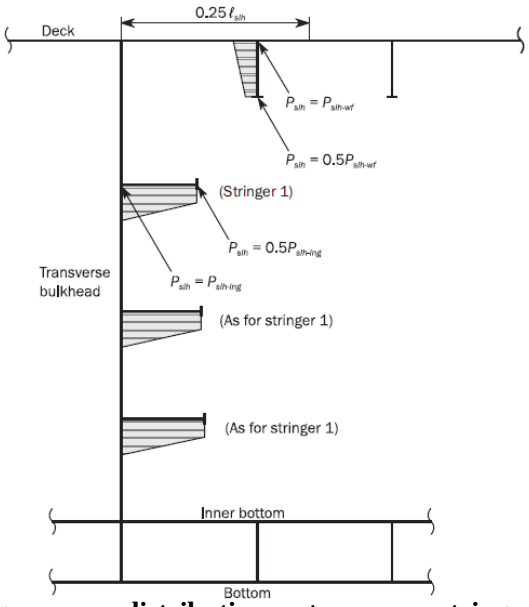


Figure 14 Sloshing pressure distribution on transverse stringers and web frames

Effective sloshing breadth b_{slh} **Table 12**

Type of longitudinal bulkhead	b_{slh}
Longitudinal tight bulkheads	$b_{slh} = \dfrac{(1+n_{WL}\alpha_{WL})(1+f_{grd}\alpha_{grd})b_{tk-h}}{(1+n_{WL})(1+f_{grd})}$
Longitudinal wash bulkheads	$b_{slh} = \dfrac{[1+(n_{WL}-1)\alpha_{WL}](1+f_{grd}\alpha_{grd})b_{tk-h}}{(1+n_{WL})(1+f_{grd})}$

where:

n_{WL} : Number of longitudinal wash bulkheads in the tank.

α_{WL} : Longitudinal wash bulkhead coefficient:

$$\alpha_{WL} = \frac{A_{OWL}}{A_{tk-L-h}}$$

For tanks with changing shape along the breadth and/or with wash bulkhead of different shape the longitudinal wash bulkhead coefficient, α_{WL}, may be taken as the weighted average of all wash bulkhead locations in the tank given as:

$$\alpha_{WT} = \frac{\sum_{i=1}^{n_{WL}} \frac{A_{OWL_i}}{A_{tk-L-h_i}}}{n_{WL}}$$

α_{grd} : Girder coefficient, to be taken as:

$$\alpha_{grd} = \frac{A_{O-grd-h}}{A_{tk-L-h}}$$

For tanks with changing shape along the breadth and/or with girder of different shape the girder coefficient, α_{grd}, may be taken as the weighted average of all girder locations in the tank given as:

$$\alpha_{grd} = \frac{\sum_{i=1}^{n_{grd}} \frac{A_{O-grd-h_i}}{A_{tk-L-h_i}}}{n_{grd}}$$

A_{OWL} : Total area of openings, in m^2, in the longitudinal section in way of the wash bulkhead below the considered filling height.

$A_{tk\text{-}L\text{-}h}$: Total longitudinal cross sectional area, in m^2, of the tank below the considered filling height.

$A_{O\text{-}grd\text{-}h}$: Total area of openings, in m^2, in the longitudinal section in way of the web frame below the considered filling height.

f_{grd} : Factor to account for number of longitudinal girders and longitudinal wash bulkheads in the tank, to be taken as:

$$f_{grd} = \frac{n_{grd}}{1 + n_{WL}}$$

n_{grd} : Number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank.

$b_{tk\text{-}h}$: Breadth of cargo tank, in m, at considered filling height.

6.4.3 Sloshing pressure in way of longitudinal bulkheads

The sloshing pressure in way of longitudinal bulkheads including wash bulkheads due to transverse liquid motion, $P_{slh\text{-}t}$, in kN/m^2, for a particular filling level, is to be taken as:

$$P_{slh-t} = 7\rho_{slh} g f_{slh} \left(\frac{b_{slh}}{B} - 0.3 \right) GM^{0.75}$$

where:

b_{slh} : Effective sloshing breadth defined in [6.4.2].

GM : Metacentric height, given in Ch 4, Sec 3, [2.1.1].

For the calculation of sloshing pressure in ballast tanks the 'ballast condition' is to be used for oil tankers and the 'normal ballast condition' for bulk carriers.

For the calculations of sloshing pressure in cargo tanks of oil tankers, the 'partial load condition' is to be used.

f_{slh} : Coefficient defined in [6.3.3].

6.4.4 Sloshing pressure on internal girders or longitudinal stringers adjacent to longitudinal bulkheads

For tanks with internal girders or stringers, the sloshing pressure acting on the girder/web frame adjacent to longitudinal bulkheads and longitudinal wash bulkhead, $P_{slh\text{-}grd}$, in kN/m^2, provided it is located within 0.25 b_{slh} from the bulkhead, is to be taken as:

$$P_{slh-grd} = P_{slh-t} \left(1 - \frac{s_{grd}}{b_{slh}} \right)^2$$

where:

b_{slh} : Effective sloshing breadth defined in [6.4.2].

$P_{slh\text{-}t}$: Sloshing pressure due to transverse liquid motion acting on longitudinal bulkhead, as defined in [6.4.3].

s_{grd} : Distance from longitudinal bulkhead to girder under consideration, in m.

The distribution of pressure across stringers is given in Figure 15. The distribution of pressure across longitudinal girders is similar to the deck web frame shown in Figure 14.

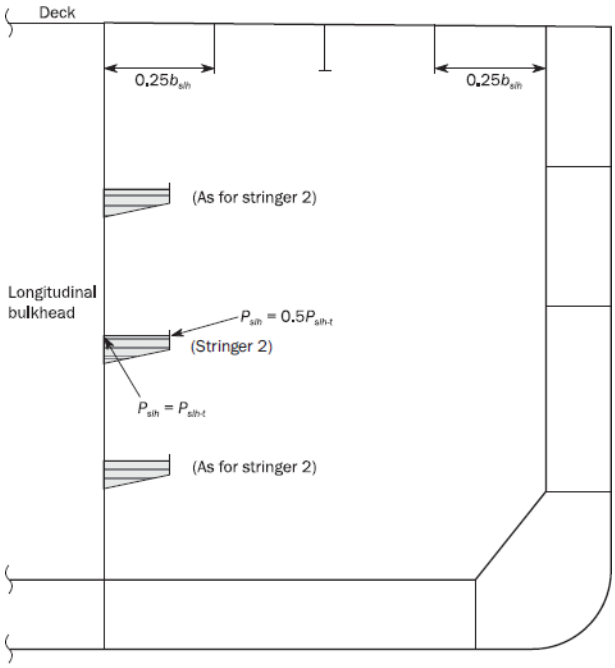


Figure 15 Sloshing pressure distribution on longitudinal stringers and girders

7 DESIGN PRESSURE FOR TANK TESTING

7.1 Definition

7.1.1

The actual strength testing is to be carried out in accordance with Ch1, Sec 2, [3.8.4]. In order to assess the structure, static design pressures are to be applied.

The design pressure for tank testing, P_{ST}, in kN/m^2, is to be taken as:

$P_{ST} = 10(z_{ST} - z)$

where:

z_{ST}: Design testing load height, in m, as defined in Table 13.

Design testing load height z_{ST} **Table 13**

Compartment	z_{ST}
Double bottom tanks (1)	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{bd}$
Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$ $z_{ST} = z_{top} + 0.1P_{PV}$
Ballast hold	$z_{ST} = z_h + 0.9$
Chain locker	$z_{ST} = z_c$
Independent tanks	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

Compartment	z_{ST}
where: z_{bd} : Z coordinate, in m, of the bulkhead deck. z_h : Z coordinate, in m, of the top of hatch coaming. z_c : Z coordinate, in m, of the top of the chain pipe. (1) For double bottom tanks connected with hopper side tanks, topside tanks or double side tanks, z_{ST} corresponding to "Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank, cofferdams" is applicable.	

Section 7 DESIGN LOAD SCENARIOS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

V_{BM} : Design vertical bending moment, in kNm.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p}$: Permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in kNm, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hull girder hogging or sagging still water bending moment $M_{sw\text{-}f}$ for seagoing operation in the flooded condition, in kNm, as defined in Ch 4, Sec 4, [2.2.4].

$M_{wv\text{-}LC}$: Vertical wave bending moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec4, [3.5.2].

HBM : Design horizontal bending moment, in kNm.

$M_{wh\text{-}LC}$: Horizontal wave bending moment for a considered dynamic load case, in kNm, as defined in Ch4, Sec 4, [3.5.4].

TM : Design torsional moment, in kNm.

$M_{wt\text{-}LC}$: Wave torsional moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec 4, [3.5.5].

VSF : Design vertical shear force, in kN.

Q_{sw} : Permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN, as defined in Ch 4, Sec 4, [2.3.1] or Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN, as defined in Ch 4, Sec 4, [2.3.2] or Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible hull girder positive and negative still water shear force for seagoing operation in the flooded condition, in kN, as defined in Ch 4, Sec 4, [2.3.5].

$Q_{wv\text{-}LC}$: Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 4, Sec 4, [3.5.3].

P_{ex} : Design external pressure, in kN/m^2.

P_S : Static sea pressure at considered draught, in kN/m^2, as defined in Ch 4, Sec 5, [1.2.1].

P_W : Dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [1.3.2] to Ch 4, Sec 5, [1.3.8].

P_D : Green sea load for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [2.2.3] and Ch 4, Sec 5, [2.2.4].

P_{in} : Design internal pressure, in kN/m^2.

P_{ST} : Tank testing pressure, in kN/m^2, see Ch 4, Sec 6, [7.1.1].

P_{ls} : Static liquid pressure in tank, in kN/m^2, as defined in Ch 4, Sec 6, [1.2].

P_{ld} : Dynamic liquid pressure in tank for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [1.3].

P_{bs} : Dry bulk cargo static pressure, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.2].

P_{bd} : Dry bulk cargo dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.3].

P_{fs} : Static pressure in compartments and tanks in flooded condition, in kN/m^2, as defined in Ch 4, Sec 6, [1.4.1].

P_{fd} : Dynamic pressure in compartments and tanks in flooded condition, in kN/m^2, as defined in Ch 4, Sec 6, [1.5.1]

$P_{dl\text{-}s}$: Static pressure on non-exposed decks and platforms, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1].

$P_{dl\text{-}d}$: Dynamic pressure on non-exposed decks and platforms for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1]

$F_{U\text{-}s}$: Static load acting on supporting structures and securing systems for heavy units or cargo, equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

$F_{U\text{-}d}$: Dynamic load acting on supporting structures and securing systems for heavy units of cargo equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

P_{SL} : Bottom slamming pressure, in kN/m^2, as defined in Ch 4, Sec 5, [3.2]

P_{FB} : Bow impact pressure, in kN/m², as defined in Ch 4, Sec 5, [3.3].
P_{slh} : Sloshing pressure, in kN/m², as defined in Ch 4, Sec 6, [6].

1 GENERAL

1.1 Application

1.1.1

This section gives the design load scenarios that are to be used for:

- Strength assessment by prescriptive and direct analysis (Finite Element Method, FEM) methods, as given in [2].
- Fatigue assessment by prescriptive and direct analysis (FEM) methods, as given in [3].

1.1.2

For the strength assessment, the principal design load scenarios consist of either S (Static) loads or S+D (Static + Dynamic) loads. In some cases, the letter 'A' prefixes the S or S+D to denote that this is an accidental design load scenario. There are some additional design load scenarios to be considered which relate to impact (I) loads, sloshing (SL) loads and fatigue (F) load.

2 DESIGN LOAD SCENARIOS FOR STRENGTH ASSESSMENT

2.1 Principal design load scenarios

2.1.1

The principal design load scenarios are given in Table 1.

Principal design load scenarios **Table 1**

Design load scenario			Harbour and sheltered water and testing	Seagoing conditions With extreme sea loads	Ballast water exchange (4)	Accidental flooded conditions (4)	
Load components			Static (S)	Static +Dynamic (S+D)	Static + Dynamic (S+D)	Static (S)	Static + Dynamic (A : S+D)
Hull Girder	*VBM*		$M_{sw\text{-}p}$	$M_{sw} + M_{wv\text{-}LC}$	$M_{sw} + M_{wv\text{-}LC}$	$M_{sw\text{-}f}$ (2)	$M_{sw\text{-}f} + M_{wv\text{-}LC}$ (3)
	HBM		-	$M_{wh\text{-}LC}$	$M_{wh\text{-}LC}$	-	$M_{wh\text{-}LC}$ (3)
	VSF		$Q_{sw\text{-}p}$	$Q_{sw} + Q_{wv\text{-}LC}$	$Q_{sw} + Q_{wv\text{-}LC}$	-	$Q_{sw\text{-}f} + Q_{wv\text{-}LC}$ (3)
	TM		-	$M_{wt\text{-}LC}$	$M_{wt\text{-}LC}$	-	-
Local Loads	P_{ex}	External deck for green sea	-	P_D	-	-	-
		Hull envelope	P_S	$P_S + P_W$	$P_S + P_W$	-	-
	P_{in}	Ballast tanks (1)	$Max(P_{ls}, P_{ST})$	$P_{ls} + P_{ld}$	$P_{ls} + P_{ld}$	-	-
		Liquid cargo tanks			-	-	
		Other tanks			-	-	
		Watertight boundaries	-	-	-	P_{fs}	$P_{fs} + P_{fd}$
		Cargo holds	P_{bs}	$P_{bs} + P_{bd}$	-		
	P_{dk}	Internal decks for dry spaces	$P_{dl\text{-}s}$	$P_{dl\text{-}s} + P_{dl\text{-}d}$	-	-	-
		External deck for distributed loads	$P_{dl\text{-}s}$	$P_{dl\text{-}s} + P_{dl\text{-}d}$	-	-	-
		External deck for heavy units	$F_{U\text{-}s}$	$F_{U\text{-}s} + F_{U\text{-}d}$	-	-	-

Design load scenario	Harbour and sheltered water and testing	Seagoing conditions With extreme sea loads	Ballast water exchange (4)	Accidental flooded conditions (4)	
Load components	Static (S)	Static +Dynamic (S+D)	Static + Dynamic (S+D)	Static (S)	Static + Dynamic (A : S+D)

(1) WB cargo hold is considered as ballast tank except for design load scenario 'ballast water exchange'.
(2) M_{swf} used for hull local scantling of watertight bulkhead
(3) Hull girder strength check is performed according to Ch 5, Sec 1 for bulk carriers having a freeboard length L_{LL} of 150 m or above
(4) Applicable to prescriptive assessment only

2.2 Additional design load scenarios

2.2.1

The design load scenarios to be considered for sloshing, bottom slamming and bow impact are given in Table 2.

Design load scenarios for impact and sloshing conditions **Table 2**

Design load scenario / Load components			Bow impact Impact (I)	Bottom Slamming Impact (I)	Sloshing Sloshing (SL)
Hull Girder		VBM	-	-	M_{sw}
		HBM	-	-	-
		VSF	-	-	-
		TM	-	-	-
Local Loads	P_{ex}	External deck for green sea	-	-	-
		Hull envelope	P_{FB}	P_{SL}	-
	P_{in}	Ballast tanks	-	-	P_{slh}
		Liquid cargo tanks			
		Other tanks			
		Watertight boundaries		-	-
		Cargo holds(1)	-	-	-
	P_{dk}	Internal decks for dry spaces	-	-	-
		External deck for distributed loads	-	-	-
		External deck for heavy units	-	-	-

(1) Sloshing assessment is not to be considered for water ballast cargo holds of bulk carriers.

3 DESIGN LOAD SCENARIOS FOR FATIGUE ASSESSMENT

3.1 Design load scenarios

3.1.1

The design load scenarios for fatigue assessment are given in Table 3.

Design load scenarios for fatigue assessment **Table 3**

Design load scenario / Load components		Fatigue: Static + Dynamic (F: S+D)
Hull Girder	VBM	$M_{sw} + M_{wv\text{-}LC}$
	HBM	$M_{wh\text{-}LC}$
	VSF	$Q_{sw} + Q_{wv\text{-}LC}$

Design load scenario			Fatigue: Static + Dynamic (F: S+D)
Load components			
	TM		$M_{wt\text{-}LC}$
Local Loads	P_{ex}	External deck for green sea	-
		Hull envelope	$P_S + P_W$
	P_{in}	Ballast tanks (1)	$P_{ls} + P_{ld}$
		Liquid cargo tanks	
		Other tanks	
		Watertight boundaries	-
		Cargo holds	$P_{bs} + P_{bd}$
	P_{dk}	Internal decks for dry spaces	-
		External deck for distributed loads	-
		External deck for heavy units	-
(1) WB cargo hold is considered as ballast tank except for design load scenario ‘ballast water exchange’.			

Section 8 LOADING CONDITIONS

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

l : Distance from propeller centreline to the waterline, in m.

D_p : Propeller diameter, in m.

M_{Full} : Cargo mass, in t, as defined in Ch4, Sec 6.

M_H : Cargo mass, in t, as defined in Ch4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch4, Sec 6.

M_{BLK} : Maximum cargo mass in cargo holds in block loading conditions, in t, as defined in Ch4, App 1.

$C_{BM\text{-}LC}$: Coefficient taken as the percentage of permissible SWBM, defined in Table 2 to Table 9 and Table 12 to Table 21.

$C_{SF\text{-}LC}$: Coefficient taken as the percentage of permissible SWSF, defined in Table 2 to Table 9 and Table 12 to Table 21.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$:Longitudinal position, in m, of respectively the aft and forward bulkhead of the mid-hold of the FE model.

EA : Empty hold in alternate loading condition.

FA : Full hold in alternate loading condition.

T_{H1}, T_{H2}, T_{H3}, T_{H4}: Minimum permissible draught, in m, in harbour condition as defined in Ch 4, App 1.

1 APPLICATION

1.1 Ships having a freeboard length L_{LL} of 150m or above

1.1.1

The requirements in [2] to [5] are applicable to ships having a freeboard length L_{LL} of 150 m or above.

1.1.2 Design loading conditions for strength assessment

Design loading conditions for strength assessment are given in [2] to [4]. The design loading conditions common to both oil tankers and bulk carriers are given in [2]. Specific design loading conditions for oil tankers and bulk carriers are given in [3] and [4] respectively.

Unless otherwise specified, each of the design seagoing conditions is to be investigated for the arrival and departure conditions.

1.1.3

These requirements are not intended to prevent conditions to be included in the loading manual for which calculations are to be submitted. It is not intended to replace in any way the required loading manual/instrument.

1.1.4

Loading conditions from the loading manual, which are not covered in [2] to [4], if any, are to be considered.

1.1.5 Standard design load conditions for fatigue assessment

The standard design loading conditions for fatigue assessment are given in [5].

1.2 Bulk carriers having a freeboard length L_{LL} less than 150 m

1.2.1

The severest loading condition from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength given in Ch5 and for local strength check of plating, ordinary stiffeners and primary supporting members given in Ch6 and Pt 2, Ch1, Sec 3 and Pt 2, Ch1, Sec 4.

The requirements in [2] are applicable to ships having a freeboard length L_{LL} less than 150 m.

1.3 Dynamic load cases

1.3.1 Seagoing conditions

Unless otherwise specified, each of the design seagoing conditions are to be investigated for all dynamic load cases.

1.3.2 Beam and oblique sea dynamic load cases

For FE load analysis, the beam sea and oblique sea dynamic load cases calculated for port and starboard sides are to be applied on the model to obtain the results for both model sides.

For ship with structure symmetrical about the centreline, the beam sea and oblique sea dynamic load cases calculated for portside may be applied only to the model (i.e. dynamic load cases on starboard side may be omitted) provided the results (yield and buckling) are mirrored.

2 COMMON DESIGN LOADING CONDITIONS

2.1 Definitions

2.1.1

In general, the design cargo and ballast loading conditions, based on the amount of bunker, fresh water and stores at departure and arrival, are to be considered for the still water bending moment and shear force calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting are to be submitted and included in the loading manual.

2.1.2 Departure conditions

The departure conditions are to be based on bunker tanks not taken less than 95% full and other consumables taken at 100% capacity. In case of liquefied gas fuel tank, the filling level is to be based on the definition in International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF code) 6.8.

2.1.3 Arrival conditions

The arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

2.2 Partially filled ballast tanks

2.2.1 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions unless:

- Longitudinal strength of hull girder given in Ch 5, Sec 1 and Ch 8, Sec 3 is to comply with loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.
- For bulk carriers having a freeboard length L_{LL} of 150 m or above, longitudinal strength of hull girder in flooded condition given in Ch 5, Sec 1 is to comply with loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.

The corresponding full, empty and partially filled tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in [2.3.1], [3.1.1] or [4.1.1]. Where multiple tanks are intended to be partially filled, all combinations of empty, full and partially filled at intended levels for those tanks are to be investigated. These requirements are not applicable to ballast water exchange using the sequential method.

2.2.2 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in [2.2] applies to peak ballast tanks only.

2.3 Seagoing conditions

2.3.1

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Homogeneous cargo loading condition including a condition at the scantling draught. Homogeneous loading conditions are to not include filling of ballast tanks in departure conditions.

b) Ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. All cargo tanks/holds are to be empty including cargo tanks/holds suitable for the carriage of water ballast at sea. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L_{LL}.

c) Conditions covering ballast water exchange procedures, if any, with the calculations of intermediate conditions just before and just after ballasting and/or deballasting any ballast tank.

2.4 Harbour and sheltered water conditions

2.4.1

The following harbour and sheltered water conditions are to be included in the loading manual:

a) Conditions representing typical complete loading and unloading operations.

b) Docking condition afloat.

c) Propellers inspection afloat condition, in which the propeller shaft centreline is at least $D_p/4$ above the waterline in way of the propeller. Ships with podded propulsion system arrangements are to be individually considered by the Society.

ISC 2.4.1a The afloat condition for podded propulsion system inspection is to be included in the loading manual. Consideration may be given to inspection requirements of equipment supplier for the system.

2.5 Loading conditions

2.5.1 Alternative design

For structural arrangement not covered by this section, the loading conditions, including loading pattern, corresponding draught, still water bending moment and shear forces are to be agreed by the Society.

ISC 2.5.1a Where the hull structural arrangement is different from that covered by the Rules, for load conditions used for FE analysis, they are to be determined according to ISC Appendix B of this PART.

3 OIL TANKERS

3.1 Specific design loading conditions

3.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The fore peak water ballast tank is to be full, if fitted. If upper and lower fore peak tanks are fitted, the lower is required to be full and the upper tank may be full, partially full or empty. All the cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea. The draught at the forward perpendicular is not to be less than that for the normal ballast condition. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L_{LL}.

b) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

c) Any specified non-uniform distribution of loading.

d) Conditions with high density cargo including the maximum design cargo density, when applicable.

e) Design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks. This design condition is for assessment of hull strength and is not intended for ship operation.

3.1.2 Additional loading conditions

The following additional loading conditions are to be included in the loading manual if the ship is specifically approved and intended to be operated in such conditions:

a) Seagoing ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Reg. 18.
b) Seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of 0.9 T_{SC}.
c) Seagoing loading conditions with cargo tanks less than 25% full with the combination of mean ship's draught greater than 0.9 T_{SC}.
d) Seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 t/m^3 or greater and a mean ship's draught of 0.6T_{SC}.
e) For ships arranged with cross ties in the centre cargo tank, seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port an starboard wing cargo tanks exceeds 25% of the filling height in the wing cargo tank.

3.2 Design load combinations for direct strength analysis

3.2.1

The design load combinations for FE analysis are given in Table 1 as follows:

Design load combination for oil tankers **Table 1**

	Midship cargo hold region	Outside midship cargo hold region	Foremost cargo tanks	Aftmost cargo tanks
Tankers with two oil-tight bulkheads	Table 2	Table 4	Table 6	Table 8
Tankers with one centreline oil-tight bulkhead	Table 3	Table 5	Table 7	Table 9
Note 1: Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds				

3.2.2

For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 *L*, the draughts given in Table 2, Table 4, Table 6 and Table 8 are subject to special consideration by the Society.

ISC 3.2.2a For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15L, the draughts corresponding to the load conditions are determined according to ISC Appendix B of this PART.

3.2.3

For tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11 *L*, the draughts given in Table 3, Table 5, Table 7 and Table 9 are subject to special consideration by the Society.

ISC 3.2.3a For tankers with one oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.11L, the draughts corresponding to the load conditions are determined according to ISC Appendix B of PART9-1.

3.2.4

For seagoing conditions, the dynamic load cases required to be investigated for each loading pattern are indicated in Table 2 to Table 9. Dynamic load cases are defined in Ch 4, Sec 2.

3.2.5 Ships with structure symmetrical about centreline

For ships with structure symmetrical about the centreline, the loading pattern mirrored about centreline of another pattern may be omitted provided the results (yield and buckling) are mirrored, e.g. Table 2 A7b, A12b.

3.2.6 Tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks

For tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks, loading patterns A7 in Table 2, Table 4, Table 6 and Table 8 is to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading condition is included in the ship loading manual. The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch4, Sec 3.

If loading pattern A7 is not considered, an operational restriction describing that the difference in filling level between corresponding port and starboard wing cargo tanks is not to exceed 25% of the filling height in the wing cargo tank, is to be added in the loading manual.

Loading pattern A7 needs not be examined for tankers with a cross tie arrangement in the wing cargo tanks.

3.2.7

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A3 and harbour loading pattern A13, with all cargo tanks abreast empty, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of $0.65T_{SC}$ and $0.7T_{SC}$ respectively. If conditions in the ship loading manual specify greater draughts for loading pattern A3 or A13, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.8

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A5 and harbour loading pattern A11, with all cargo tanks abreast fully loaded, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of $0.65T_{SC}$ and $0.6T_{SC}$ respectively. If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.9

For loading patterns A1, A2, B1, B2 and B3, with cargo tank(s) empty, in Table 2 to Table 9, a minimum ship draught of $0.9T_{SC}$ is to be used in the analysis. If conditions in the ship loading manual specify greater draughts for loading patterns with empty cargo tank(s), then the maximum specified draught for the actual condition is to be used.

3.2.10 Ballast conditions

Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading patterns A8 or B7 in Table 2 or Table 3 are to be examined.

If the actual loading pattern as specified in the loading manual is different from load pattern A8 or B7 then:

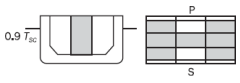
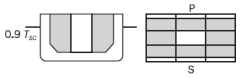
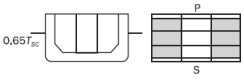
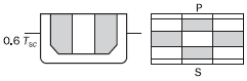
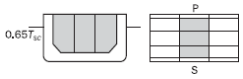
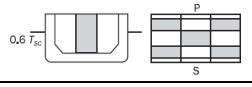
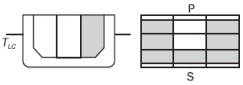
a) The actual loading patterns are to be substituted for the loading pattern A8 or B7 with the following calculation conditions:
   - Draught to be taken as $T_{BAL\text{-}E}$,
   - $C_{BM\text{-}LC}$ = 100% (sag.),
   - $C_{SF\text{-}LC}$ = 100%,
   - 100% filling of the considered tanks carrying ballast water.

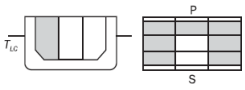
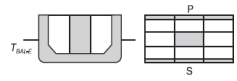
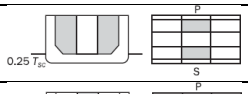
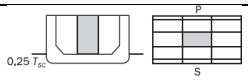
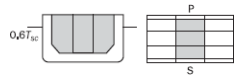
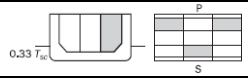
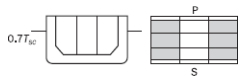
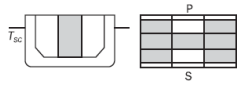
b) The strength assessment is to be carried out for all the dynamic load cases as defined in Ch 4, Sec 2.

c) An operational restriction corresponding to the analysed condition is to be added in the loading manual.

The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch 4, Sec 3.

Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable tomidship cargo hold region **Table 2**

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region		
Seagoing conditions							
A1		0.9 T_{SC}	100% (sagging)	100%	HSM-1	BSP-1P/S	N/A
			100% (hog.)	100%	HSM-2 FSM-2	BSP-1P/S	OST-2P/S OSA-1P/S
A2		0.9 T_{SC}	100% (sagging)	100%	HSM-1	BSR-1P /S BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	N/A
A3		0.65 T_{SC}	100% (hogging)	100% [4] Max SFLC	HSM-2	N/A	N/A
				100% [5] Max SFLC	HSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% [6] Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
A4		0.6 T_{SC}	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OSA-2P/S
5		0.65 T_{SC}	100% (sagging)	100% [4] Max SFLC	HSM-1	N/A	N/A
				100% [5] Max SFLC	HSA-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% [6] Max SFLC	HSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
A6		0.6 T_{SC}	100% (hogging)	100%	HSM-2	BSR-1P/S BSP-1P/S	OSA-1P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region		
A7b		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S
A8		$T_{BAL\text{-}E}$	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OSA-2P/S
Harbour and testing conditions							
A9		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A10		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A11		$0.6T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A		
				100% (3) Max SFLC	N/A		
A12a (1)		$0.33T_{SC}$	N/A	N/A	N/A		
A12b (1)		$0.33T_{SC}$	N/A	N/A	N/A		
A13		$0.7T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A		
				100% (3) Max SFLC	N/A		
A14		T_{SC}	100% (hogging)	100%	N/A		

(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

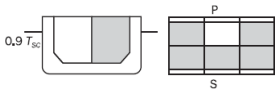
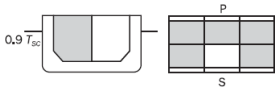
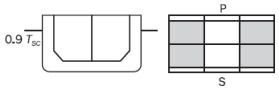
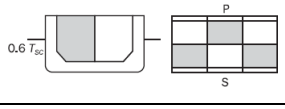
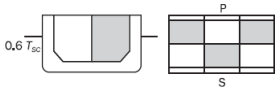
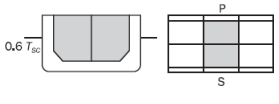
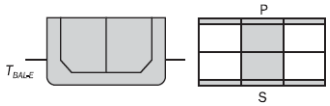
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

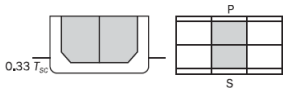
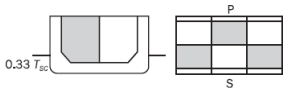
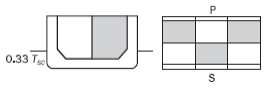
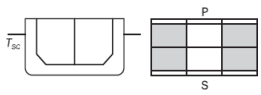
(4) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid- hold.

(5) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(6) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$

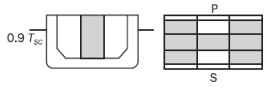
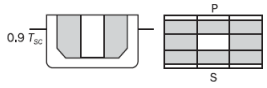
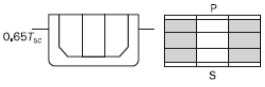
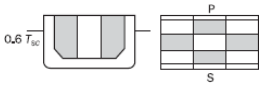
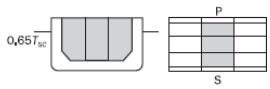
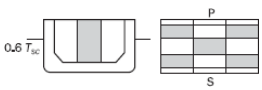
Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers applicable to midship cargo region **Table3**

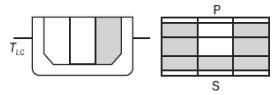
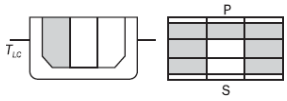
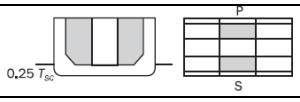
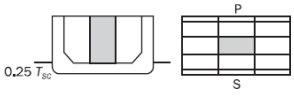
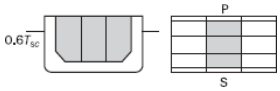
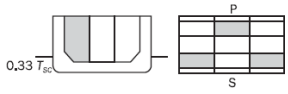
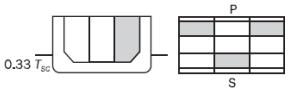
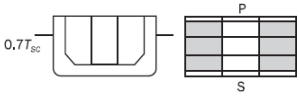
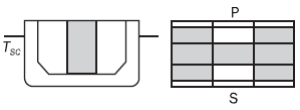
No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region		
Seagoing conditions							
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSP-1P BSR-1P	OST-2P
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1S BSP-1S	OST-2S
B3		$0.9T_{SC}$	100% (hogging)	100% (2) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100% (2) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (2) Max SFLC	HSM-1 FSM-1	N/A	N/A
B4		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1P	OSA-2P/S
B5		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1S	OSA-2P/S
B6		$0.6T_{SC}$	100% (sagging)	100% (2) Max SFLC	HSM-1	N/A	N/A
				100% (2) Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (2) Max SFLC	HSM-2	N/A	N/A
B7		$T_{BAL\text{-}E}$	100% (sagging)	100%	HSM-1	BSP-1P/S	N/A
Harbour and testing conditions							

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region
B8		0.33T_{SC}	100% (sagging)	100% (1) Max SFLC	N/A
				100% (2) Max SFLC	N/A
B9		0.33T_{SC}	100% (sagging)	75%	N/A
B10		0.33T_{SC}	100% (sagging)	75%	N/A
B11		T_{SC}	100% (hogging)	100% (1) Max SFLC	N/A
				100% (2) Max SFLC	N/A

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(3) For the mid-hold where $x_{b\text{-}aft} \leqslant 0.5L$ and $x_{b\text{-}fwd} \geqslant 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid- hold.
(4) For the mid-hold where $x_{b\text{-}aft} \leqslant 0.5L$ and $x_{b\text{-}fwd} \geqslant 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(5) This load combination is to be considered only For the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.

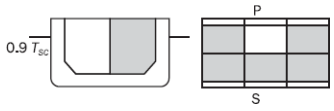
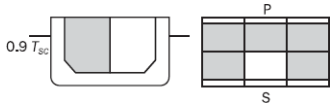
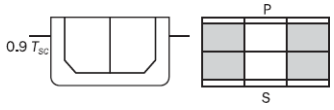
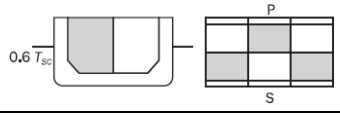
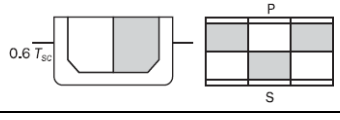
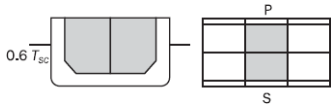
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable to outside midship cargo hold region **Table 4**

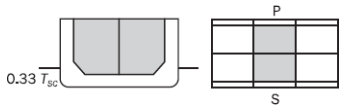
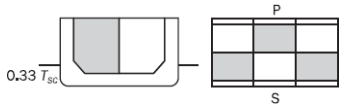
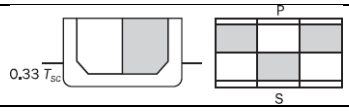
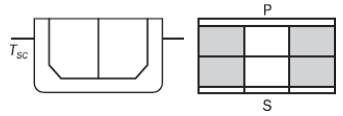
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aft region	Forward region
Seagoing conditions						
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S,	HSM-1, BSP-1P/S,
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OST-2P/S, OSA-1P/S,	HSM-2, FSM-2 BSP-1P/S,
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S,	HSM-1, FSM-1 BSP-1P/S, OSA-2P/S,
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OSA-1P/S	HSM-2, BSP-1P/S,
A3		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2	HSM-2 FSM-2
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S,
			0%	100% Max SFLC	HSM-1	HSM-1
				100%	N/A	BSP-1P/S, OSA-2P/S,
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S, BSR-1P/S,	HSM-1 BSP-1P/S, BSR-1P/S, OSA-2P/S,
A5		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1	HSM-1
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S
			0%	100% Max SFLC	HSM-2	HSM-2
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2 BSP-1P/S BSR-1P/S	HSM-2, BSP-1P/S BSR-1P/S OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aft region	Forward region
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S BSR-1P, BSR-2S OSA-1P/S OSA-2P/S, OST-2P	HSM-2, FSM-2 BSP-1P/S BSR-1P, BSR-2S OSA-2P/S
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S BSR-2P, BSR-1S OSA-1P/S OSA-2P/S, OST-2S	HSM-2, FSM-2 BSP-1P/S BSR-2P, BSR-1S OSA-2P/S
Harbour and testing conditions						
A9		0.25T_{SC}	100% (sagging)	100%	N/A	
A10		0.25T_{SC}	100% (sagging)	100%	N/A	
A11		0.6T_{SC}	100% (sagging)	100%(2) Max SFLC	N/A	
				100%(3) Max SFLC	N/A	
A12a (1)		0.33T_{SC}	N/A	N/A	N/A	
A12b (1)		0.33T_{SC}	N/A	N/A	N/A	
A13		0.7T_{SC}	100% (hogging)	100%(2) Max SFLC	N/A	
				100%(3) Max SFLC	N/A	
A14		T_{SC}	100% (hogging)	100%	N/A	

(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

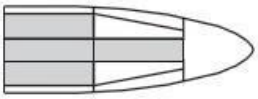
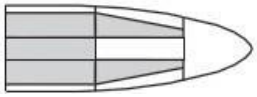
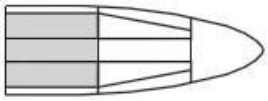
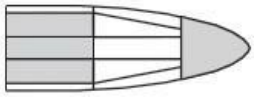
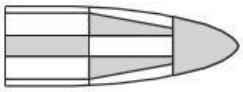
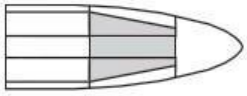
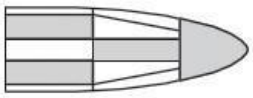
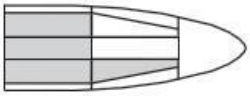
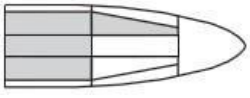
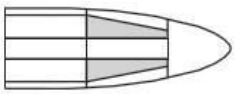
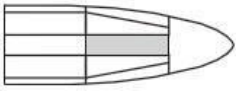
Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers pplicable to outside midship cargo hold region **Table 5**

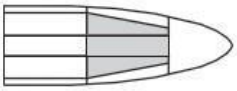
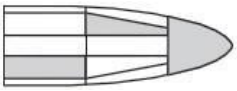
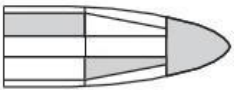
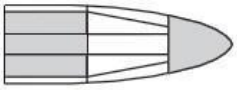
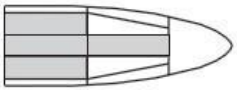
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Aft region	Forward region
Seagoing conditions						
B1		0.9T_{SC}	100% (sagging)	100%	HSM-1, FSM-2 BSP-1P/S OSA-1S	HSM-1 BSP-1P/S OSA-2S
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S OSA-1P OST-2P/S	HSM-2, FSM-2 BSP-1P/S OSA-2S
B2		0.9T_{SC}	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S OAS-1P	HSM-1 BSP-1P/S OSA-2P
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S OSA-1S OST-2P/S	HSM-2, FSM-2 BSP-1P/S OSA-2P
B3		0.9T_{SC}	100% (hogging)	100% (1) Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100%	BSR-1P/S BSR-1P/S	BSR-1P/S
			0%	100% (1) Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100%	BSP-1P/S	BSP-1P/S
B4		0.6T_{SC}	100% (sagging)	75%	HSM-1 BSR-1P/S	HSM-1 BSP-1P/S OSA-2P/S
B5		0.6T_{SC}	100% (sagging)	75%	HSM-1 BSR-1P/S	HSM-1 BSP-1P/S OSA-2P/S
B6		0.6T_{SC}	100% (sagging)	100% (1) Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100% (2) Max SFLC	OST-1P/S	OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Aft region	Forward region
			0%	100% (1) Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100% (2) Max SFLC	OSA-2P/S	OSA-2P/S
Harbour and testing conditions						
B8		0.33T_{SC}	100% (sagging)	100% (1) Max SFLC	N/A	
				100% (2) Max SFLC	N/A	
B9		0.33T_{SC}	100% (sagging)	100% (2) Max SFLC	N/A	
B10		0.33T_{SC}	100% (sagging)	75%	N/A	
B11		T_{SC}	100% (hogging)	100% (1) Max FLC	N/A	
				100% (2) Max SFLC	N/A	

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

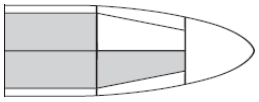
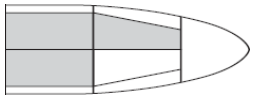
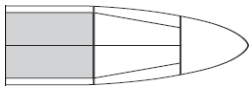
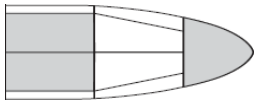
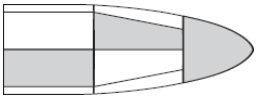
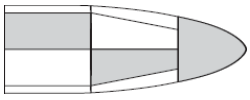
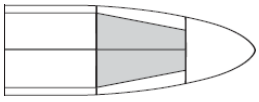
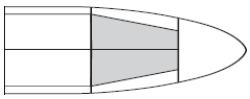
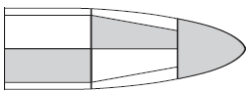
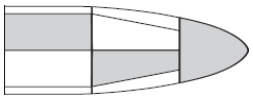
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for foremost cargo hold **Table 6**

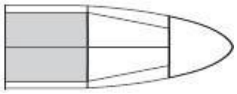
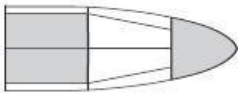
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S OSA-2P/S, OST-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, OSA-2P/S
A3-1		$0.65T_{SC}$	100% (sagging)	100%	HSM-1、 OSA-2P/S
A3-2 (1)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-2P/S
			100% (sagging)	100% Max SFLC	HSM-1
				100%	OSA-2P/S
A4 (1)		$0.6T_{SC}$	50% (hogging)	100%	FSM-1,BSP-1P/S, OSA-2P/S
A5		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
A6 (1)		$0.6T_{SC}$	50% (hogging)	100%	OSA-2P/S
A7a		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1,BSP-1P/S, BSR-1P/S,OST-1P/S, OSA-2P/S
A7b		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1,BSP-1P/S, BSR-1P/S, OST-1P/S, OSA-2P/S
Harbour and testing conditions					
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
A11		$0.6T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A12-a(1) (4)		$0.33T_{SC}$	N/A	N/A	N/A
A12-b(1) (4)		$0.33T_{SC}$	N/A	N/A	N/A
A13 (1)		$0.7T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A14		T_{SC}	100% (sagging)	100%	N/A

(1) 100% filling of all fore peak water ballast tanks.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(4) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

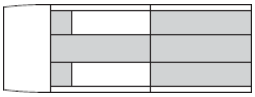
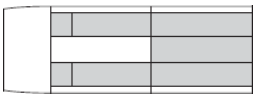
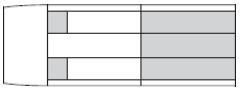
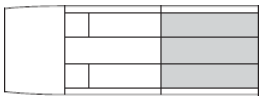
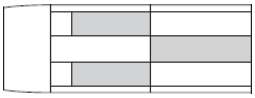
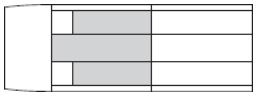
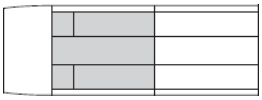
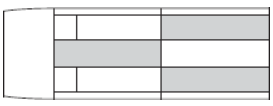
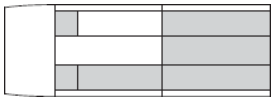
Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for foremost cargo hold **Table 7**

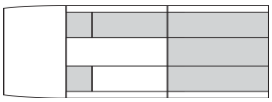
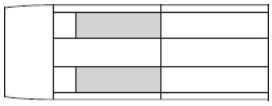
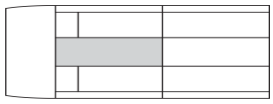
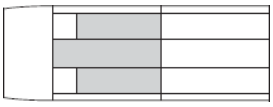
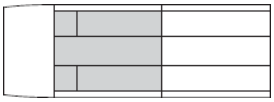
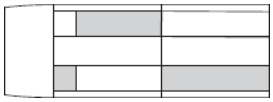
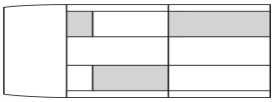
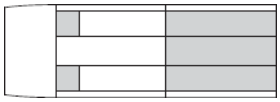
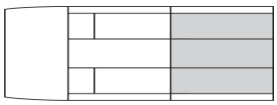
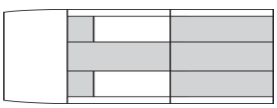
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
B1		0.9T_{SC}	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B2		0.9T_{SC}	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B3-1		0.9T_{SC}	100% (sagging)	100%	HSM-1 BSP-1S/P, OSA-2S/P,
B3-2(1)		0.9T_{SC}	0%	100% Max SFLC	HSM-2,
				100%	BSP-1S/P, OSA-2S/P,
			100% (sagging)	100% Max SFLC	HSM-1, FMS-1
				100%	BSP-1S/P, OST-1S/P, OSA-2P/S
B4(1)		0.6T_{SC}	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B5 (1)		0.6T_{SC}	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B6		0.6T_{SC}	0%	100% Max SFLC	HSM-1
				100%	OSA-2P/S
			100% (hogging)	100% Max SFLC	HSM-2, FSM-2,
				100%	OSA-2P/S
Harbour and testing conditions					
B8		0.33T_{SC}	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
B9 (1)		0.33T_{SC}	100% (hogging)	75%	N/A
B10 (1)		0.33T_{SC}	100% (hogging)	75%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
B11-1		T_{SC}	100% (sagging)	100%	N/A
B11-2 (2)		T_{SC}	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A

(1) 100% filling of all fore end water ballast tanks.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

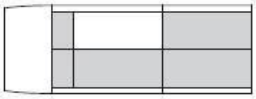
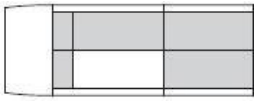
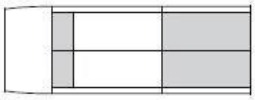
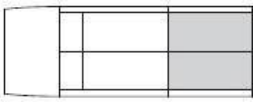
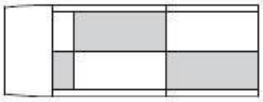
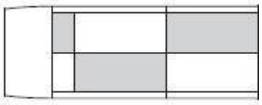
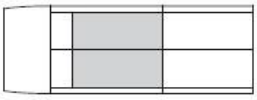
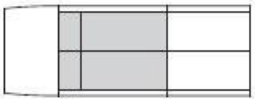
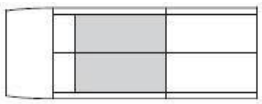
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for aftmost cargo hold **Table 8**

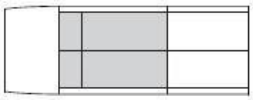
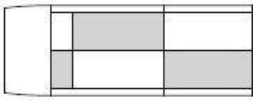
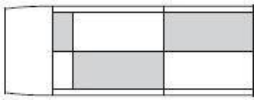
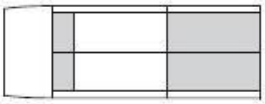
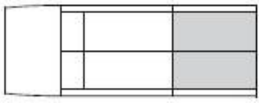
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	FSM-1, HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, OSA-1P/S BSP-1P/S, BSR-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSR-1P/S,OST-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, FSM-2,OSA-1P/S
A3-1(1) (2)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2,FSM-2
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S
A3-2(1) (3)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S, OST-1P/S
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, OSA-1P/S, OSA-2P/S
A5-1(2)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2, FSM-1
				100%	BSP-1P/S
A5-2(3)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2
				100%	BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2, FSM-2
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S OSA-1P/S

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
Harbour and testing conditions					
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A
A11-1 (2)		$0.6T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
A11-2 (3)		$0.6T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
A-12a (4)		$0.33T_{SC}$	N/A	N/A	N/A
A-12b (4)		$0.33T_{SC}$	N/A	N/A	N/A
A13-1 (1)(2)		$0.7T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
A13-2 (1) (3)		$0.7T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
		$0.7T_{SC}$	100% (sagging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
A14		T_{SC}	100% (hogging)	100%	N/A
			100% (sagging)	100%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead. (2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead. (3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead. (4) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied. (5) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold. (6) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.					

Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for the aftmost cargo hold **Table 9**

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B2		$0.9\ T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B3-1(1) (2)		$0.9\ T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	BSP-1P/S
B3-2(1) (3)		$0.9T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2, FSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S
B4		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B5		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B6-1(2)		$0.6\ T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
B6-2(3)		$0.6\ T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	HSA-2, BSR-1P/S,
Harbour and testing conditions					
B8-1(2)		$0.33T_{SC}$	100% (hogging)	100% (4) Max SFLC	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
B8-2 (3)		$0.33T_{SC}$	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
B9		$0.33T_{SC}$	100% (hogging)	75%	N/A
B10		$0.33T_{SC}$	100% (hogging)	75%	N/A
B11-1 (1)(2)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
B11-2 (1)(3)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.
(2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.
(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead.
(4) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(5) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

4 BULK CARRIERS

4.1 Specific design loading condition

4.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Cargo loading conditions as defined in [4.1.2] to [4.1.4].

b) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The propeller immersion l/D_p is to be at least 60%. The trim is to be by the stern and is not to exceed 0.01 5 L_{LL}. The moulded forward draught is not to be taken less than the smaller of 0.03 L_{LL} or 8 m.

4.1.2 Cargo loading condition for BC-C

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at scantling draught with all ballast tanks empty.

4.1.3 Cargo loading condition for BC-B

As required for BC-C, plus:

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density is taken equal to 3.0 t/m^3, and all cargo holds are taken with the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at scantling draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is different from 3.0t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0t/m^3 then the additional service feature {maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch 1, Sec 1, [3.2.1].

4.1.4 Cargo loading condition for BC-A

As required for BC-B, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3.0t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at scantling draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional service feature {Holds *a, b,* …may be empty}.

In such cases where the design cargo density applied is different from 3.0t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0 t/m^3 then the additional service feature {Holds *a, b,* … may be empty with maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch1, Sec 1, [3.2.1].

4.1.5 Additional ballast conditions

The following ballast conditions are to be included in the loading manual for longitudinal strength assessment:

- Ballast conditions with all ballast tanks 100% full,
- Heavy ballast conditions with all ballast tanks 100% full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100% full.
  Where more than one hold is adapted and designated for the carriage of water ballast at sea, it is not required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

4.1.6 Steel coils or heavy cargoes

The following note is to be included in the loading manual:

"Where the ship engages in a service carrying such cargoes as steel coils or heavy cargoes that may have an adverse effect on the local strength of the double bottom and which is not described as cargo in the loading manual, the maximum permissible and the minimum required mass of cargo are to be considered specially."

4.2 Design load combinations for direct strength analysis

4.2.1 Applicable general loading patterns

The following loading patterns are to be applied:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at scantling draught.

b) Any cargo hold carrying minimum 50% of M_H, with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at scantling draught.

c) Any cargo hold taken empty, with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at the deepest ballast draught. Where a topside and double bottom tank are permanently connected as a common tank, the following conditions are to be considered:
   - The topside and double bottom tank empty,
   - The topside and double bottom tank full.

4.2.2 Multiport conditions

The following multiport conditions are applicable to all types of bulk carriers except when the service feature {no MP} is assigned:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught.
b) Any cargo hold taken empty with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at 83% of scantling draught.
c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the scantling draught. This requirement to the mass of the cargo and fuel oil tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast.
d) Any two adjacent cargo holds being empty with the next holds being full, with all double bottom tanks and fuel oil tank in way of the cargo hold being empty, at 75% of scantling draught.

4.2.3 Alternate conditions

The following alternate conditions are applicable to BC-A only:

a) Cargo holds which are intended to be empty at scantling draught, being empty with all double bottom tanks and fuel oil tanks in way of the cargo hold also being empty.
b) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H, in the partially filled condition with highest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.
c) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H in the full condition with lowest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.
d) If the ship is intended to operate in alternate block load condition, any two adjacent cargo holds are to be loaded with the next holds being empty, carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at scantling draught. In operation the maximum allowable mass is to be limited to the maximum cargo load according to the design loading conditions.

4.2.4 Heavy ballast condition

The following condition applies to ballast holds only:

- Cargo holds which are designed as ballast water holds, being 100% full of ballast water including hatchways, with all double bottom tanks and fuel oil tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper, stool, and double bottom tanks are empty

4.2.5 Additional harbour condition for all bulk carriers

The following additional harbour conditions apply to all bulk carriers:

a) At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the scantling draught in seagoing condition, but is not to exceed the mass allowed at scantling draught in the seagoing condition. The minimum required mass may be reduced by the same amount.

b) Any single cargo hold holding the maximum allowable seagoing mass at 67% of scantling draught, in harbour condition with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty.

c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught, in harbour condition.

4.2.6 Design load combinations for direct strength analysis

The loading patterns to be considered in the direct strength analysis of bulk carriers are summarised in Table 10. Load combinations providing the calculations details for each loading pattern are given in Table 12 to Table 21.

Applicable loading patterns according to additional service features Table 10

Loading pattern	Requirement	BC-			BC- {no MP}		
		A	B	C	A	B	C
Full load in homogeneous condition	[4.2.1] item a	×	×	×	×	×	×
Slack load	[4.2.1] item b	×	×	×	×	×	×
Deepest ballast	[4.2.1] item c	×	×	×	×	×	×
Multiport-1	[4.2.2] item a	×	×	×			
Multiport-2	[4.2.2] item b	×	×	×			
Multiport-3	[4.2.2] item c	×	×	×			
Multiport-4	[4.2.2] item d	×	×	×			
Alternate load partial	[4.2.3] items a & b	×			×		
Alternate load full	[4.2.3] items a & c	×			×		
Alternate block load	[4.2.3] item d	×			×		
Heavy ballast	[4.2.4]	×	×	×	×	×	×
Harbour condition	[4.2.5]	×	×	×	×	×	×

4.2.7

The design load combinations for FE analysis are given as follows:

Design load combinations for Bulk Carriers Table 11

	Midship cargo hold region	Outside midship cargo hold region	Aftmost cargo hold	Foremost cargo hold
BC-A – EA	Table 12	Table 15	N/A	N/A
BC-A – FA	Table 13	Table 16	Table 18	Table 20
BC- B & BC-C	Table 14	Table 17	Table 19	Table 21
Note 1: Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds				

4.3 Hold mass curves

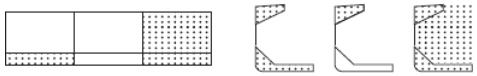
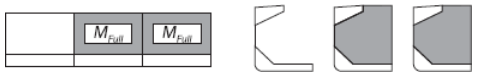
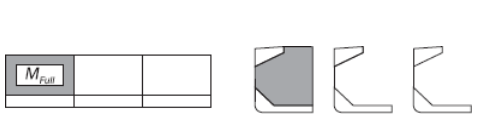
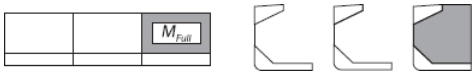
4.3.1

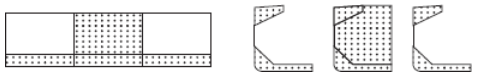
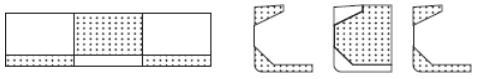
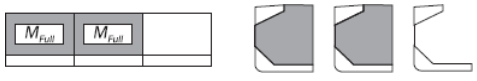
Based on the design loading criteria, as given in [4.2.1] to [4.2.5] except [4.2.4], hold mass curves for each single hold, as well as for any two adjacent holds are to be included in the loading manual and the loading instrument. The maximum allowable or minimum required cargo mass in a cargo

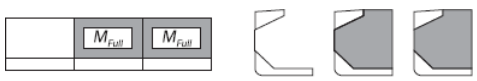
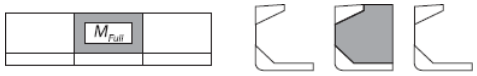
hold, or in two adjacent loaded holds is related to the net load on the double bottom. The net load on the double bottom is a function of draught, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

4.3.2
Hold mass curves are to be calculated according to Ch 4, App 1 showing maximum allowable and minimum required masses as a function of draught in seagoing condition as well as during loading and unloading in harbour.

FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - midship cargo hold region **Table 12**

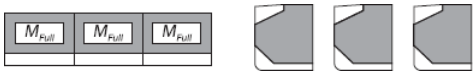
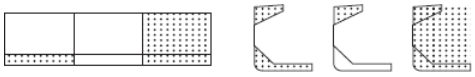
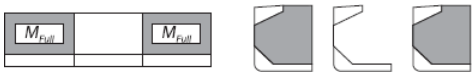
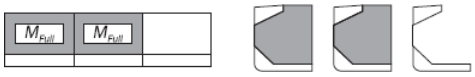
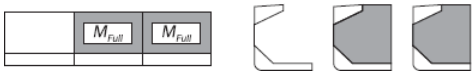
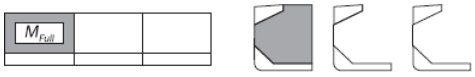
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1[2]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2[1]	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
5[3][4]	Deepest ballast [4.2.1] item c		$T_{Bal\text{-}H}$	100% (hog.)	100%	FSM-2 BSR-1P/S OST-2P/S
				100% (hog.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
6	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/S
7	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/S
8	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
9	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
10[2]	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%[8] Max SFLC	FSM-2
					100%[9] Max SFLC	FSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S OST-1P/S

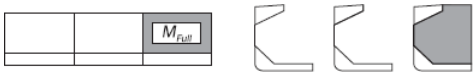
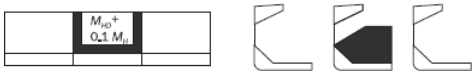
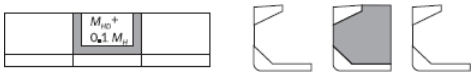
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
					100%[10] Max SFLC	HSM-1
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100%[8] Max SFLC	FSM-2 HSM-2
					100%[9] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S
					100%[10] Max SFLC	HSM-1
12[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
13[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
14[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%[10] Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100%[8] Max SFLC	HSM-1
					100%[9] Max SFLC	HSM-1
					100%	BSR-1P/S
15[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

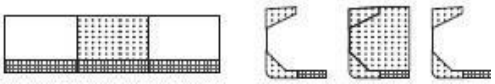
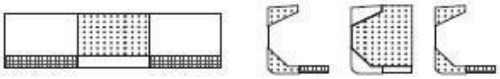
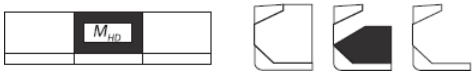
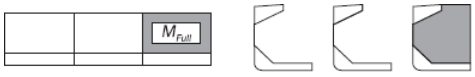
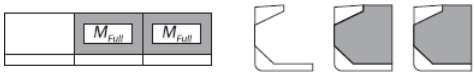
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
17	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
18	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
				100% (sag.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
19(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

(1) Loading pattern No. 1 with the cargo mass MFull and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming MSW = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) This condition is to be considered for the empty hold which is assigned as ballast hold, if any.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the midhold.
(10) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(11) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(12) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(13) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - midship cargo hold region **Table13**

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
Seagoing conditions						
1	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2[(1)]	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4[(3)(4)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	FSM-2, BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
	Multiport 2 [4.2.2] item b		0.83T_{SC}	100% (hog.)	100%[(8)] Max SFLC	FSM-2 HSM-2
					100%[(9)] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100%[(10)] Max SFLC	HSM-1
					100%	HSM-1
6	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

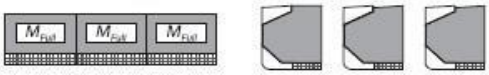
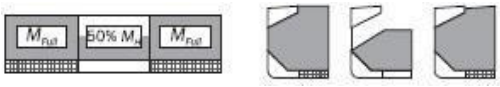
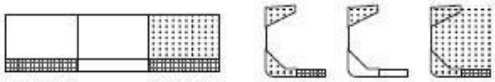
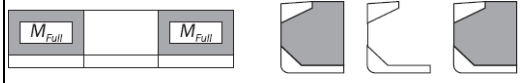
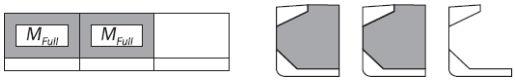
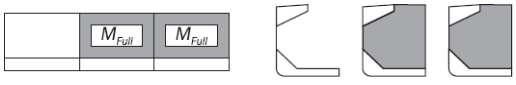
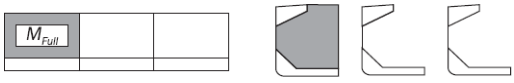
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10[2]	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%[10] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%[10] Max SFLC	FSM-1 HSM-1
					100%[10] Max SFLC	FSM-1 HSM-1
					100%	BSP-1P/S OST-1P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (sag.)	100%[10] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%[8] Max SFLC	HSM-1
					100%[9] Max SFLC	HSM-1
					100%	BSP-1P/S
12[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
13[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S

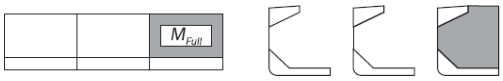
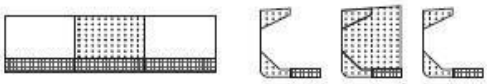
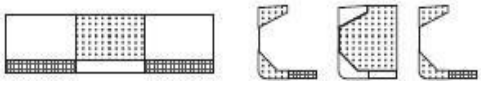
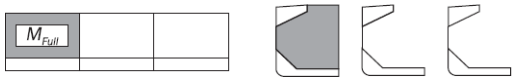
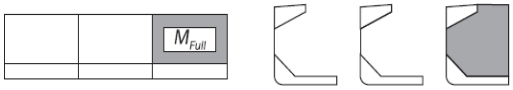
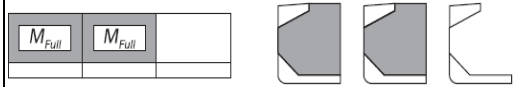
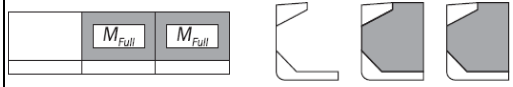
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
14[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%[10] Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100%[8] Max SFLC	HSM-1
					100%[9] Max SFLC	HSM-1
					100%	BSR-1P/S
15[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16[2]	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%[11] Max SFLC	N/A
					100%[12] Max SFLC	N/A
				100% (sag.)	100%[11] Max SFLC	N/A
					100%[12] Max SFLC	N/A
17	Harbour condition [4.2.5] items a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
18	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
19	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

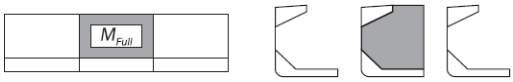
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
21(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
22(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} =100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when block loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) This condition is to be considered for the heavy cargo hold which is assigned as ballast hold, if any.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) For the mid-hold, where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid- hold.
(10) This load combination is to be considered only for the mid-hold, where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(11) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(12) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(13) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - midship cargo hold region Table 14

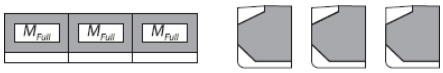
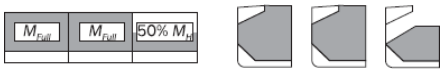
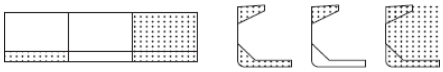
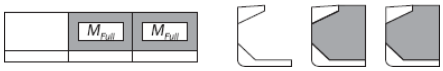
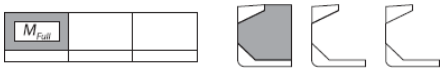
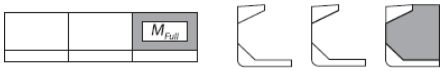
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1(1)(3)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2(2)	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4(4)(5)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	FSM-2, BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
5	Multiport 2 [4.2.2] item b		0.83T_{SC}	100% (hog.)	100%(7) Max SFLC	FSM-2 HSM-2,
					100%(8) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100%(9) Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S
6	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

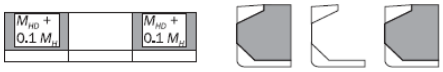
No.	Description Req[t] ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d					$0.75T_S$	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
							100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10	Heavy ballast [4.2.4]					$T_{BAL\text{-}H}$	0%	100%[(9)] Max SFLC	FSM-2 HSM-2
								100%	BSR-1P/S
							100% (sag.)	100%[(7)] Max SFLC	HSM-1
								100%[(8)] Max SFLC	HSM-1
								100%	BSR-1P/S
11[(6)]	Heavy ballast [4.2.4]a					$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
							100% (sag.)	100%	BSR-1P/S
Harbour conditions									
12	Harbour condition [4.2.5] items a					$0.67T_{SC}$	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] item a					$0.67T_{SC}$	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
14	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
15	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A

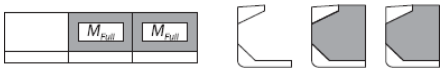
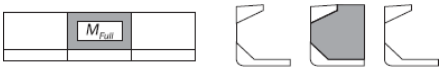
No.	Description Req^{t} ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
16	Harbour condition [4.2.5] items a and b					T_{H2}	100% (hog.)	100%(10) Max SFLC	N/A
								100%(11) Max SFLC	N/A
							100% (sag.)	100%(10) Max SFLC	N/A
								100%(11) Max SFLC	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) This condition is to be considered for the cargo hold which is assigned as ballast hold, if any.
(7) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(10) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(11) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - outside midship cargo hold region **Table15**

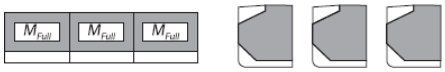
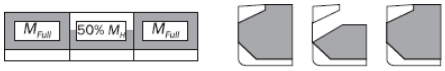
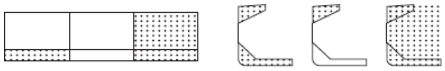
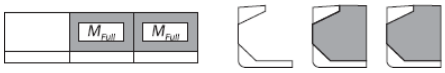
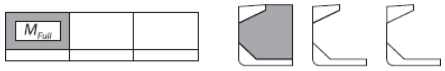
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
Seagoing conditions							
1[2]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/1S OST-1P/1S OSA-1P/1S	HSM-1 BSP-1P/1S OST-1P/1S OSA-2P/S
2[1]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/1S	BSP-1P/1S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/1S	BSP-1P/1S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/1S	BSP-1P/1S
5[3][4]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 HSA-2 BSR-1P/1S OST-2P/S	FSM-2 BSP-1P/1S BSR-1P/1S OSA-2P/S
				100% (sag.) [10]	100%	HSM-1 BSP-1P/1S	HSM-1 BSP-1P/1S BSR-1P/1S OSA-2P
6[5]	Multiport 3 [4.2.2] item c		0.67 T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/1S	HSM-1 OST-1P/1S
7[5]	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/1S	BSP-1P/1S OSA-2P/S
8[5]	Multiport 4 [4.2.2] item d		0.75 T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 BSR-1P/1S OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/1S OST-1P/1S	HSM-1 BSP-1P/1S OST-1P/1S
9[5]	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-	HSM-1 BSP-1P/1S BSR-1P/1S

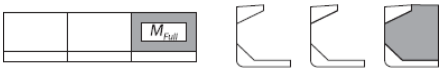
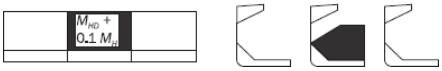
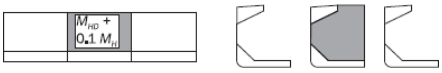
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
						1P/1S OST-1P/1S	OST-1P/1S
10(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100% Max SFLC	FSM-2, HSM-2	FSM-2, HSM-2
					100%	BSP-1P/1S OST-2P/S OSA-1P/1S	BSP-1P/1S BSR-1P/1S OST-2P/S OSA-2P/S
				0%	100%	BSP-1P/1S OST-2P/S OSA-1P/1S	BSP-1P/1S OST-2P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100% Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
					100%	BSP-1P/S OST-2P/S	BSP-1P/S BSR-1P/S OST-2P/S OSA-2P/S
				0%	100%	BSP-P/1S	HSA-1 BSP-1P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
12(2) (6)(7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
13(2) (6)(7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S OST-1P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
Harbour conditions							
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

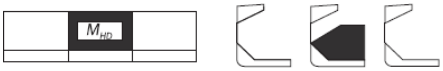
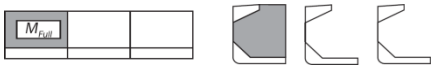
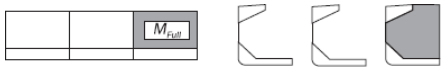
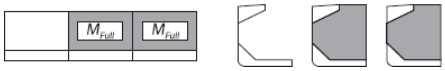
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
15	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%(8) Max SFLC	N/A	N/A
					100%(9) Max SFLC	N/A	N/A
				100% (sag.)	100%(8) Max SFLC	N/A	N/A
					100%(9) Max SFLC	N/A	N/A
17(11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
18(11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is not required when {no MP} notation is assigned.
(6) This condition is only required when this loading condition is included in the loading manual.
(7) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(8) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(10) This loading condition is required only when the ballast hold is located inside the cargo hold model.
(11) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - outside midship cargo hold region **Table 16**

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
Seagoing conditions							
1	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2[(1)]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	N/A	BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-2 HSA-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S
4[(3)] [(4)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OST-1P/S OSA-2P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		0.83T_{SC}	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
7	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1
8	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	HSM-2 FSM-2 BSR-1P/S BSP-1P/S OSA-1P/S OST-2P/S	FSM-2 BSR-2P/S OSA-2P/S
				100% (sag.)	100%	BSR-1P/S BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S

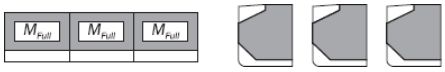
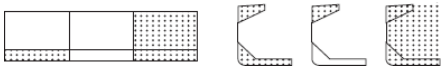
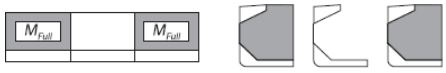
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S BSR-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S BSR-2P/S OST-1P/S
10[2]	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S OST-2P/S	BSP-1P/S OSA-2P/S OST-2P/S
					100% Max SFLC	HSM-2 FSM-2	FSM-2
				0%	100% Max SFLC	HSM-1 FSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	BSP-1P/S BSR-2P/S OSA-1P/S OSA-2P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S	OSA-1P/S OSA-2P/S
					100% Max SFLC	N/A	FSM-2, HSM-2
				0%	100% Max SFLC	HSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	OSA-1P/S OST-2P/S
12[2] [5][6] [9]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	HSA-2 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OSA-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S

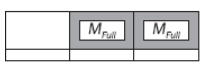
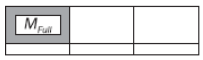
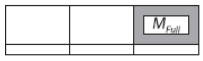
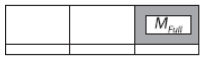
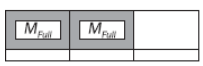
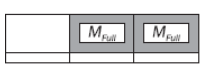
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
13[2][5][6][9]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S OST-2P/S
				100% (sag.)	100%	HSM-1 HSA-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
Harbour conditions							
14[2]	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%[7] Max SFLC	N/A	N/A
					100%[8]Max SFLC	N/A	N/A
				100% (sag.)	100% Max SFLC	N/A	N/A
					100%[8]Max SFLC	N/A	N/A
15	Harbour condition [4.2.5] item a		0.67 T_{SC}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] item a		0.67 T_{SC}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
17	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
18	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
19[9]	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
20[9]	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

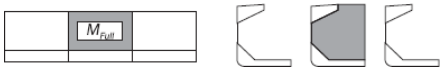
No.	Description Req[t] ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
									Aft Region	Forward region
(1) Loading pattern No. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern. (2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure. (3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed. (4) Position of ballast hold is to be adjusted as appropriate. (5) This condition is only required when this loading condition is included in the loading manual. (6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value. (7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold. (8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold. (9) This condition is only required when block loading condition is included in the loading manual.										

FE Load combinations applicable for BC-B & BC-C - outside midship cargo hold region

Table 17

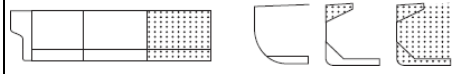
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						Aft Region	Aft Region
Seagoing conditions							
1[(1)(3)]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2[(2)]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S OST-2P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-1 HSM-2 HSA-1 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S OST-2P/S
4[(4)(5)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OSA-2P/S OST-1P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		0.83T_{SC}	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S

No.	Description Req^{t} ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
									Aft Region	Aft Region
7	Multiport 3 [4.2.2] item c					$0.67T_{SC}$	100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S
8	Multiport 4 [4.2.2] item d					$0.75T_{SC}$	100% (hog.)	100%	HSM-2 FSM-2 BSP-1P/S BSR-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 BSR-2P/S OSA-2P/S
							100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
9	Multiport 4 [4.2.2] item d					$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S BSR-2P/S
							100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S BSR-2P/S OST-1P/S
Harbour conditions										
10	Harbour condition [4.2.5] item a					$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A
11	Harbour condition [4.2.5] item a					$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A
12	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A
13	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						Aft Region	Aft Region
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%(6) Max SFLC	N/A	N/A
					100%(7) Max SFLC	N/A	N/A
				100% (sag.)	100%(6) Max SFLC	N/A	N/A
					100%(7) Max SFLC	N/A	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

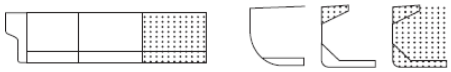
FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) – aftmost cargo hold **Table 18**

No.	Description Req[t] ref	Loading patten Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic [7] load case
Seagoing conditions						
1[2]	Full load [4.1.3]		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
2[1]	Full load [4.2.1] item a		T_{SC}	80% (sag.)	100%	FSM-1
3	Slack load [4.2.1] item c		T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4[3] [4]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	30% (hog.)	100%	FSM-1, OSA-1P/S
				30% (sag.)	100%	FSM-1 BSP-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	BSP-1P/S OST-1P/S
7[2]	Alternate load partial [4.2.3] items a and b		T_{SC}	50% (hog.)	100% Max SFLC	HSM-2
					100%	BSP-1P/S OSA-1P/S
				0%	100% Max SFLC	FSM-1
					100%	BSP-1P/S OST-1P/S OSA-1P/S

No.	Description Req[t] ref	Loading patten Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic [7] load case
8	Alternate load full [4.2.3] items a and c		T_{SC}	50% (hog.)	100% Max SFLC	HSM-2, FSM-2
					100%	BSP-1P/S, OSA-1P/S
				0%	100% Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S OSA-1P/S
9[2] [5] [6]	Alt-block load [4.2.3] item d		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions						
10	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%	N/A
				50% (hog.)	100%[7]Max SFLC	N/A
					100%[8]Max SFLC	N/A
11	Harbour condition [4.2.5] item a		0.67T_{SC}	50% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
12	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A
13[9]	Alt-block harbour condition [4.2.3] item d		T_{H3}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_H and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - aftmost cargo hold **Table 19**

No	Description Req[t]ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
Seagoing conditions									
1(1)(3)	Full load [4.1.3]					T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S OSA-1P/S
2(2)	Full load [4.2.1] item a					T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
3	Slack load [4.2.1]b					T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4(4)(5)	Deepest ballast [4.2.1] item c					$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b					0.83T_{SC}	30% (sag.)	100%	FSM-1 BSR-1P/S OSA-1P/S
							30% (hog.)	100%	FSM-1, OST-1P/S
6	Multiport 3 [4.2.2] item a					0.67T_{SC}	60% (hog.)	100%	BSP-1P/S
								100% Max SFLC	HSM-2
							0%	100% Max SFLC	HSM-1
7	Multiport 3 [4.2.2] item c					0.67T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions									
8	Harbour condition [4.2.5] items a and b					T_{H2}	100% (hog.)	100%	N/A
							50% (hog.)	100%(6) Max SFLC	N/A
								100%(7) Max SFLC	N/A
9	Harbour condition [4.2.5] items a					0.67T_{SC}	50% (hog.)	100%	N/A
							50% (sag.)	100%	N/A
10	Harbour condition [4.2.5] items a and c					T_{H1}	50% (hog.)	100%	N/A
							50% (sag.)	100%	N/A

No	Description Req^{t}ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
(1) Applicable to BC-B only. (2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern. (3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure. (4) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed. (5) Position of ballast hold is to be adjusted as appropriate. (6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold. (7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold									

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) – foremost cargo hold **Table 20**

No	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic[(7)] load case
Seagoing conditions						
1[(2)]	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2[(1)]	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4[(3)(4)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport3 [4.2.2] item c		$0.67T_{SC}$	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	FSM-2
(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100%Max SFLC	HSM-2
				0%	100%Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S
9	Alternate load full [4.2.3] items a and c		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100%Max SFLC	HSM-2
				0%	100%Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S

No	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic[7] load case
10[2][5][6][9]	Alt-block load [4.2.3] item d		T_{SC}	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
Harbour conditions						
11[2]	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%	N/A
				50% (sag.)	100%[7] Max SFLC	N/A
					100%[8] Max SFLC	N/A
12	Harbour condition [4.2.5] item a		0.67T_{SC}	100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
14[9]	Alt-block harbour condition [4.2.3] item d		T_{H3}	50% (hog.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - foremost cargo hold Table 21

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1[(1)(3)]	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2[(2)]	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4[(4)(5)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport3 [4.2.2] item c		$0.67T_{SC}$	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
Harbour conditions						
8	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%	N/A
				50% (hog.)	100%[(6)] Max SFLC	N/A
					100%[(7)] Max SFLC	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
9	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (sag.)	100%	N/A
10	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{Sw} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

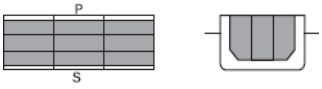
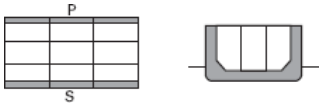
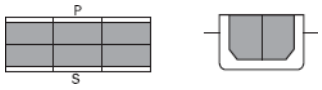
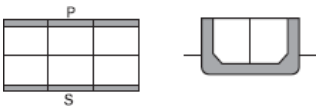
5 STANDARD LOADING CONDITIONS FOR FATIGUE ASSESSMENT

5.1 Oil tanker

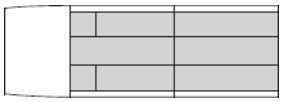
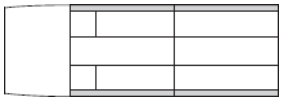
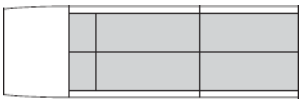
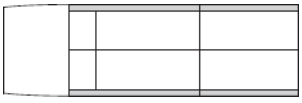
5.1.1

The standard loading conditions to be applied to oil tankers for fatigue assessment as required in Ch 9, Sec 1, [6.2], are defined in Table 22 to Table 24. Where fuel oil tanks, other oil tanks or fresh water tanks are arranged in way of the cargo hold region, the filling level of them are to be taken as full for both simplified stress analysis according to Ch 9, Sec 4 and direct strength analysis according to Ch 7 and Ch 9, Sec 5.

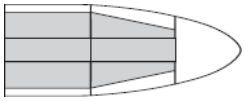
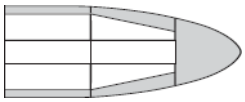
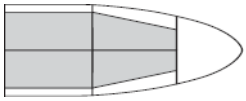
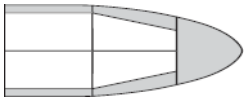
Standard design FE loading conditions for fatigue assessment of oil tankers except for foremost and aftmost cargo holds **Table 22**

No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	C_{BM-LC}:% of perm. SWBM	C_{SF-LC}:% of perm. SWSF	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

Standard design FE loading conditions for fatigue assessment of oil tankers for aftmost cargo hold **Table 23**

No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC} :% of perm. SWSF	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

Standard design FE loading conditions for fatigue assessment of oil tankers for foremost cargo hold **Table 24**

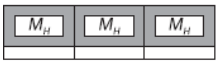
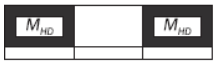
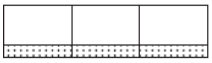
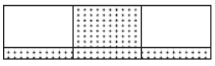
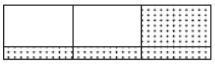
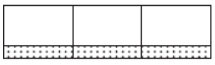
No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF (1)	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

5.2 Bulk carriers

5.2.1

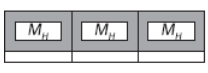
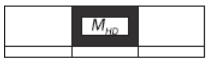
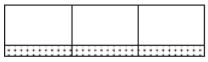
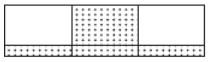
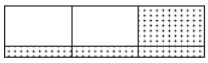
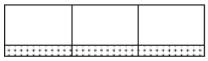
The standard loading conditions to be applied to bulk carriers for fatigue assessment as required in Ch 9, Sec 1, [6.3] are defined in Table 25, to Table 31 according to their additional service feature notations and the location of the assessed details. Where fuel oil tanks, other oil tanks or fresh water tanks are arranged in way of the cargo hold region, the filling level of them are to be taken as full for both simplified stress analysis according to Ch 9, Sec 4 and direct strength analysis according to Ch 7 and Ch 9, Sec 5.

Standard design FE Load combinations for fatigue assessment applicable to empty hold of BC-A in alternate condition (EA) - cargo hold region except aftmost and foremost cargo Holds **Table 25**

No.	Description Req^t ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% (sag.)		All
2-F(2)	Full load alternate					T_{SC}	75% (hog.)	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% (hog.)		All
4-F (2) (3)	Heavy ballast					$T_{BAL\text{-}H}$	75% (sag.)	100%	All
5-F (2) (4)						$T_{BAL\text{-}H}$	45% (hog.)	100%	All
6-F (1) (5)						$T_{BAL\text{-}H}$	45% (hog.)		All

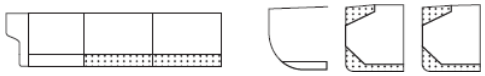
(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for empty cargo hold which is assigned as ballast hold, if any
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - cargo hold region except aftmost and foremost cargo Holds **Table 26**

No.	Description Reqt ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% （sag.）		All
2-F(2)	Full load alternate					T_{SC}	75% （hog.）	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% （hog.）		All
4-F (2) (3)	Heavy ballast					$T_{BAL\text{-}H}$	75% （sag.）	100%	All
5-F (2) (4)						$T_{BAL\text{-}H}$	45% （hog.）	100%	All
6-F (1) (5)						$T_{BAL\text{-}H}$	45% （hog.）		All

(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for loaded cargo hold which is assigned as ballast hold, if any
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Aftmost cargo hold **Table 27**

No.	Description	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F(2)	Full load alternate		T_{SC}	75% (hog.)	100%	All
3-F(1)	Normal ballast		T_{BAL}	80% (hog.)		All
4-F(1)(3)	Heavy ballast		$T_{BAL\text{-}H}$	45% (hog.)		All

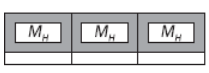
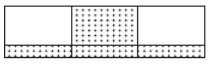
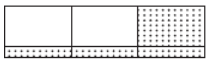
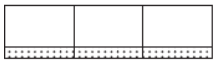
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Foremost cargo hold **Table 28**

No.	Description	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous		T_{SC}	40% （sag.）		All
2-F(2)	Full load alternate		T_{SC}	75% （hog.）	100%	All
3-F(1)	Normal ballast		T_{BAL}	80% （hog.）		All
4-F(1)(3)	Heavy ballast		$T_{BAL\text{-}H}$	45% （hog.）		All

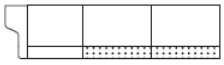
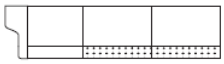
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers – cargo hold region except aftmost and foremost cargo holds **Table 29**

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% （sag.）		All
2-F(2)	Normal ballast					T_{BAL}	80% （hog.）		All
-F(2)(3)	Heavy ballast					$T_{BAL\text{-}H}$	75% （sag.）	100%	All
4-F(2)(4)						$T_{BAL\text{-}H}$	45% （hog.）	100%	All
5-F(1)(2)						$T_{BAL\text{-}H}$	45% （hog.）		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for cargo hold which is assigned as ballast hold, if any.
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

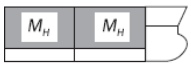
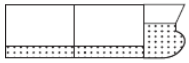
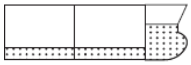
Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers – Aftmost cargo hold **Table 30**

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous					T_{SC}	40% (sag.)		All
2-F (1)	Normal ballast					T_{BAL}	80% (hog.)		All
3-F (1)	Heavy ballast					$T_{BAL\text{-}H}$	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers

Foremost cargo hold **Table 31**

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% (sag.)		All
2-F(1)	Normal ballast					T_{BAL}	80% (hog.)		All
3-F(1)	Heavy ballast					$T_{BAL\text{-}H}$	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

Appendix 1 HOLD MASS CURVES

SYMBOLS

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m.

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold of two adjacent cargo holds, in m.

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold of two adjacent cargo holds, in m.

M_H : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{Full} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{BLK} : The maximum cargo mass in a cargo hold of two adjacent cargo holds according to the block loading condition in the loading manual, in t.

T_i : In loading condition No. i, draught, in m, at mid-hold position of single cargo hold length or at mid- length of the two adjacent cargo holds considered.

T_{min} : $0.75T_{SC}$ or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m.

T_{H1} : Minimum permissible draught, in m, in harbour condition with M_{Full} in each of the two adjacent holds to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H1} = \min \begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H1} = 0.67T_{SC} - \frac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$$

T_{H2} : Minimum permissible draught, in m, in harbour condition with M_{Full} in EA holds of BC-A ships or with M_{Full} in any holds of BC-B and BC-C ships to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H2} = \min \begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15M_{Full}}{1.025\dfrac{V_H}{h}} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H2} = 0.67T_{SC} - \frac{0.15M_{Full}}{1.025\dfrac{V_H}{h}}$$

T_{H3} : Minimum permissible draught, in m, in harbour condition in case of block loading with M_{BLK} in each of the two adjacent holds of BC-A ships to be taken as:

$$T_{H3} = T_{SC} - \frac{\sum(0.15M_{BLK} + 0.1M_H)}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$$

T_{H4} : Minimum permissible draught, in m, in harbour condition with M_{HD} in FA holds of BC-A ships to be taken as:

$$T_{H4} = \min \begin{cases} 0.67 T_{SC} \\ T_{SC} - \dfrac{0.15 M_{HD} + 0.1 M_H}{1.025 \dfrac{V_H}{h}} \end{cases}$$

V_H : Volume in m^3, as defined in Ch 4, Sec 6.

V_a : Volume of the after cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3.

V_f : Volume of the forward cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3.

Σ : The sum of masses of two adjacent cargo holds.

E_A : Empty hold in alternate loading condition.

F_A : Full hold in alternate loading condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this appendix apply to bulk carriers having a freeboard length L_{LL} of 150 m or above.

1.1.2

This appendix describes the procedure to be used for determination of:

- The maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold.
- The maximum and minimum mass of cargo in any two adjacent holds as a function of the draught at mid-length of these two adjacent cargo holds.

1.1.3 General

The cargo mass curves of single cargo hold or of two adjacent cargo holds in seagoing and harbour conditions as defined in [2] and [3] are based on the loading conditions considered in Ch 4, Sec 8, [4.2]. However if the ship structure is checked for more severe loading conditions than the ones considered in Ch 4, Sec 8, [4.2.7], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

1.1.4 Loading/unloading conditions in harbour

For any bulk carrier, the maximum permissible cargo mass and the minimum required cargo mass of single cargo hold or of two adjacent cargo holds, corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

1.1.5 Maximum and minimum permissible mass expression

The maximum and minimum permissible mass in seagoing conditions, ($W_{maxS}(T_i)$, $W_{minS}(T_i)$) and in harbour condition (($W_{maxH}(T_i)$, $W_{minH}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae given in tables of [2] and [3] for the followings:

- BC-A ship not having {No MP} notation assigned,
- BC-A ship having {No MP} notation assigned,
- BC-B and BC-C ships not having {No MP} notation assigned,
- BC-B and BC-C ships having {No MP} notation assigned,

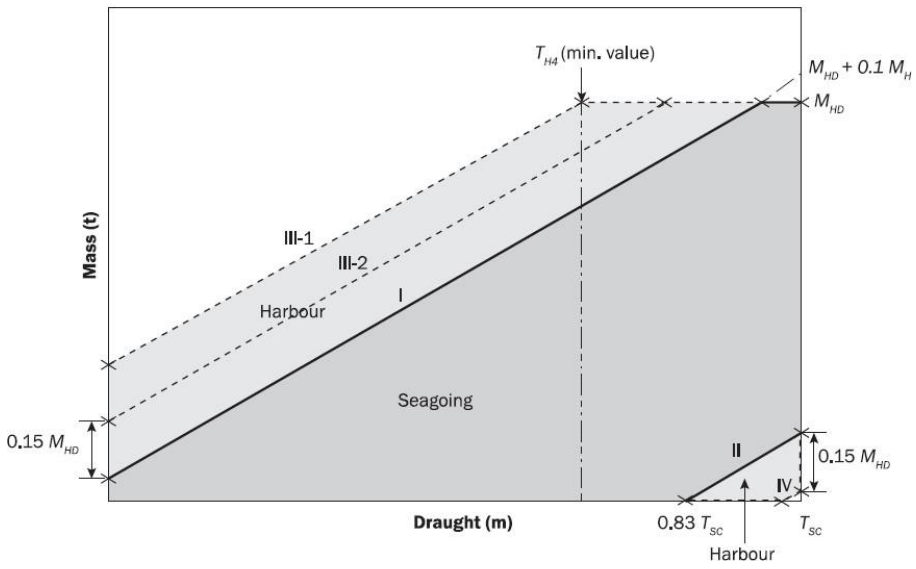
Examples for mass curve of loaded cargo holds and cargo hold which can be empty at the maximum draught for BC-A ships not having {No MP} assigned are shown in figures of the above mentioned tables.

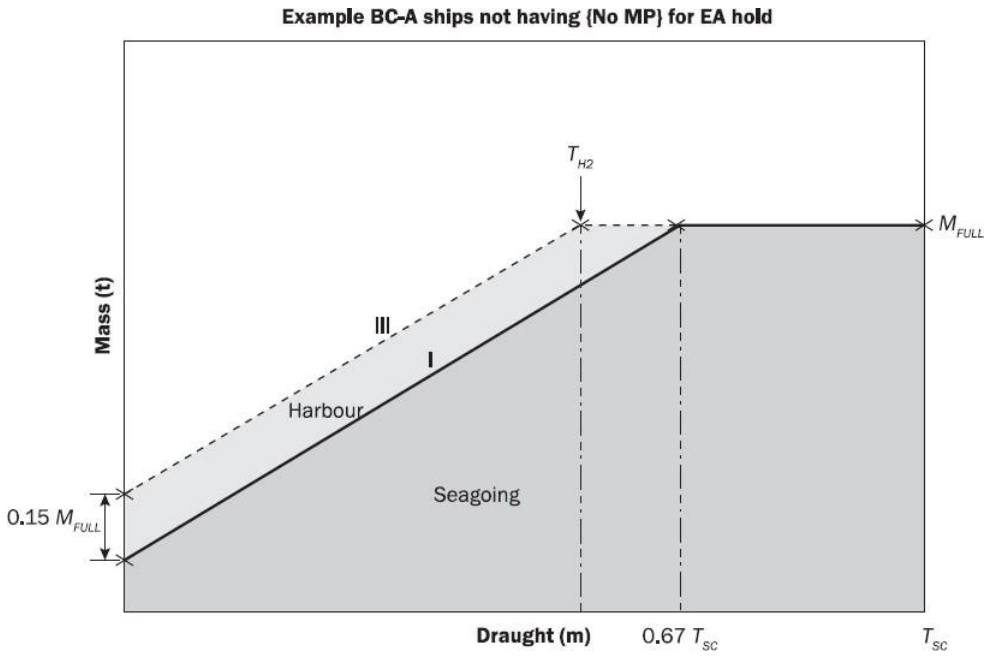
2 MAXIMUM AND MINIMUM MASSES OF CARGO IN EACH HOLD

2.1 Maximum permissible mass and minimum required mass of single cargo hold

2.1.1 BC-A ship not having {No MP} notation assigned

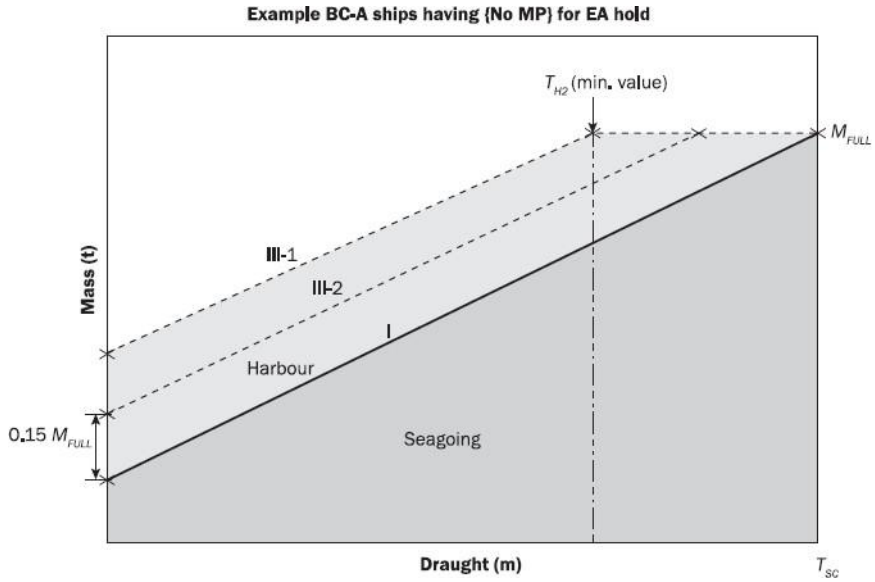
BC-A ship not having {No MP} notation assigned **Table 1**

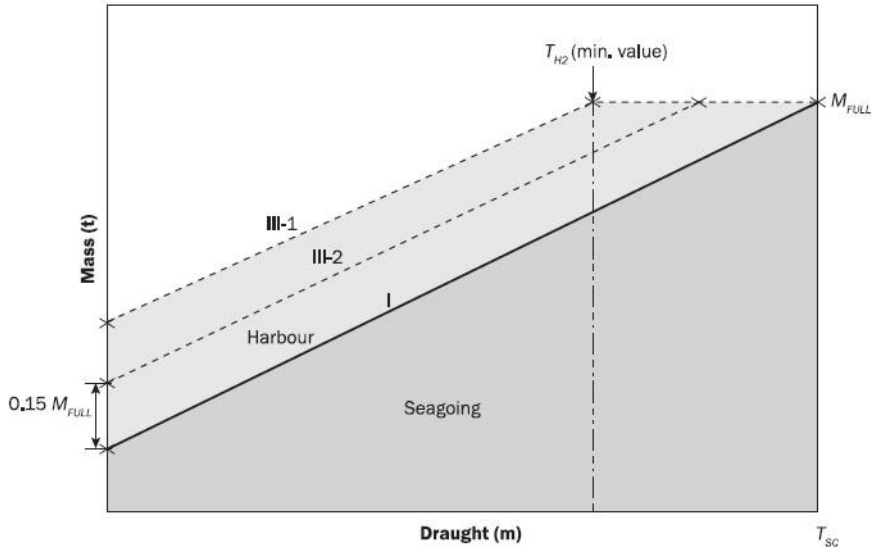
Hold	Loading conditions	Max / Min curves	Curve	Ref
FA	Seagoing	Maximum: $W_{maxS}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \leq M_{MD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}(T_i) = 1.025V_H \frac{(T_i - 0.83T_{SC})}{h} \geq 0$	II	Ch 4, Sec 8, [4.2.2] b
	Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{HD} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \leq M_{HD} \\ W_{maxS}(T_i) + 0.15M_{MD} \leq M_{MD} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch4, Sec8, [4.2.5]
		Minimum: $W_{min(Ti)} = W_{minS}(T_i) - 0.15M_{HD} \geq 0$	IV	Ch4,Sec, [4.2.5]
		Example BC-A ships not having {No MP} for FA holds  		

<table>
<tr><td rowspan="5">EA</td><td rowspan="2">Seagoing</td><td>Maximum:
$W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \leq M_{Full}$</td><td>I</td><td>Ch 4, Sec 8, [4.2.2] a</td></tr>
<tr><td>Minimum:
$W_{minS}(T_i) = 1.025V_H \frac{(T_i - T_{SC})}{h} \geq 0$</td><td>II</td><td>Ch 4, Sec 8, [4.2.3] a</td></tr>
<tr><td rowspan="2">Harbour</td><td>Maximum:
$W_{max(Ti)} = W_{maxS}(T_i) + 0.15M_{Full} \geqslant M_{Full}$</td><td>III</td><td>Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td>Minimum:
$W_{min(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \geqslant 0$</td><td>IV</td><td>Ch 4, Sec 8, [4.2.2] a</td></tr>
<tr><td colspan="4">Example BC-A ships not having (No MP) for EA hold
 
</td></tr>
</table>

2.1.2 BC-A ship having {No MP} notation assigned

BC-A ship having {No MP} notation assigned **Table 2**

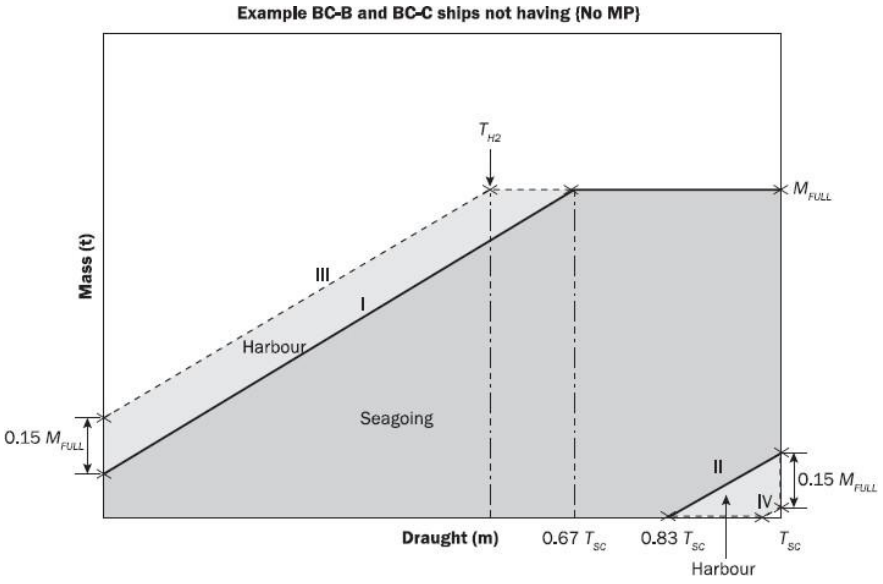
Hold	Loading conditions	Max / Min curves	Curve	Ref
FA	Seagoing	Maximum: $W_{maxS}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{HD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}(T_i) = \min \begin{cases} 1.025V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
	Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{HD} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}(T_i) + 0.15M_{HD} \le M_{HD} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{HD} \geqslant 0$	IV	Ch 4, Sec 8, [4.2.5]
				

<table>
<tr><td rowspan="4">EA</td><td rowspan="2">Seagoing</td><td>Maximum:
$W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(T_{SC} - T_i)}{h} \leq M_{Full}$</td><td>I</td><td>Ch 4, Sec 8, [4.2.1] a</td></tr>
<tr><td>Minimum:
$W_{minS}(T_i) = 1.025V_H \frac{(T_i - T_{SC})}{h} \geq 0$</td><td>II</td><td>Ch 4, Sec 8, [4.2.3] a</td></tr>
<tr><td rowspan="2">Harbour</td><td>Maximum:
$W_{maxH}(T_i) = \max \begin{cases} M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \leq M_{Full} \\ W_{maxS}(T_i) + 0.15M_{Full} \leq M_{Full} \end{cases}$</td><td>III-1
III-2</td><td>Ch 4, Sec 8, [4.2.6] a
Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td>Minimum:
$W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \geqslant 0$</td><td>IV</td><td>Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td colspan="4">Example BC-A ships having (No MP) for EA hold
 
</td></tr>
</table>

2.1.3 BC-B and BC-C ships not having {No MP} notation assigned

BC-B and BC-C ships not having {No MP} notation assigned **Table 3**

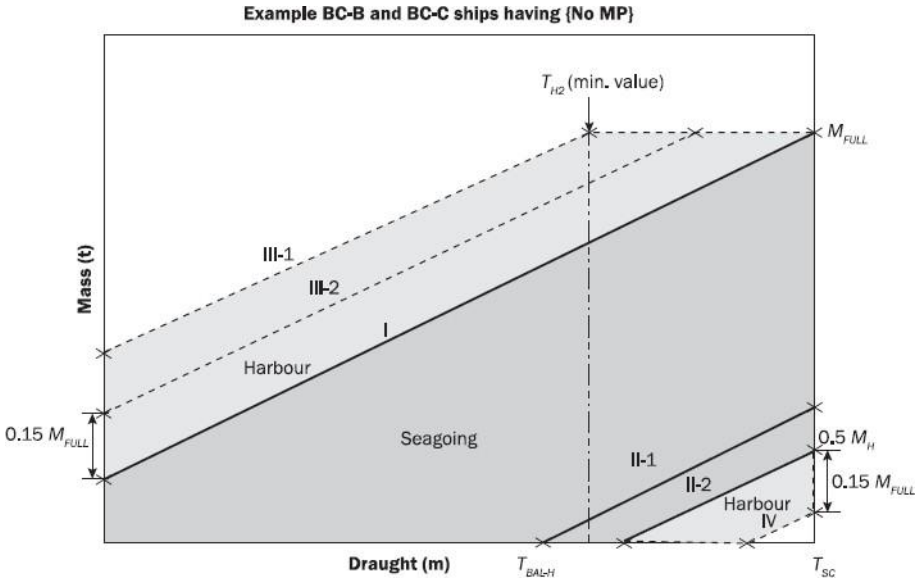
Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \leq M_{Full}$	I	Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}(T_i) = 1.025V_H \frac{(T_i - 0.83T_{SC})}{h} \geq 0$	II	Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum: $W_{maxH}(T_i) = W_{maxS}(T_i) + 0.15M_{Full} \leq M_{Full}$	III	Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \geqslant 0$	IV	Ch 4, Sec 8, [4.2.5]



2.1.4 BC-B and BC-C ships having {No MP} notation assigned

BC-B and BC-C ships having {No MP} notation assigned **Table 4**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.1] a
	Minimum: $W_{minS}(T_i) = \min \begin{cases} 1.025V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch4,Sec8, [4.2.5]
	Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \geqslant 0$	IV	Ch4,Sec8, [4.2.5]



3 MAXIMUM AND MINIMUM MASSES OF CARGO OF TWO ADJACENT HOLDS

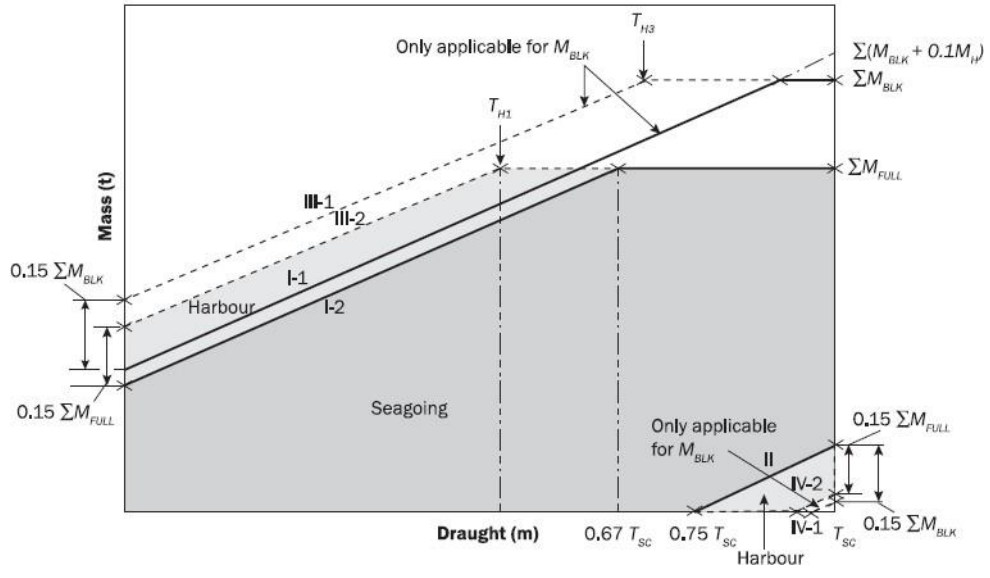
3.1 Maximum permissible mass and minimum required mass of two adjacent holds

3.1.1 BC-A ships not having {No MP} notation assigned

BC-A ship not having {No MP} notation assigned **Table 5**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \max \begin{cases} \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_{SC} - T_i) \le M_{Full} \end{cases}$	I -1(1) I -2	Ch 4,Sec8, [4.2.3]d Ch 4, Sec 8, [4.2.2]c
	Minimum: $W_{minS}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_{SC}) \ge 0$	II	Ch 4, Sec8, [4.2.2]d
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} W_{maxS}(T_i) + 0.15\sum M_{BLK} \le M_{BLK} \\ W_{maxS}(T_i) + 0.15\sum M_{Full} \le M_{Full} \end{cases}$	III-1(1) III-2	Ch 4,Sec8, [4.2.5] Ch 4,Sec8, [4.2.5]
	Minimum: $W_{minH}(T_i) = \min \begin{cases} W_{minS}(T_i) - 0.15\sum M_{BLK} \le 0 \\ W_{minS}(T_i) - 0.15\sum M_{Full} \le 0 \end{cases}$	IV-1(1) IV-2	Ch 4,Sec8, [4.2.5] Ch 4,Sec8, [4.2.5]
(1) This limit curve is only applicable when block loading condition is included in the loading manual.			

Example BC-A ships not having {No MP} for two adjacent holds



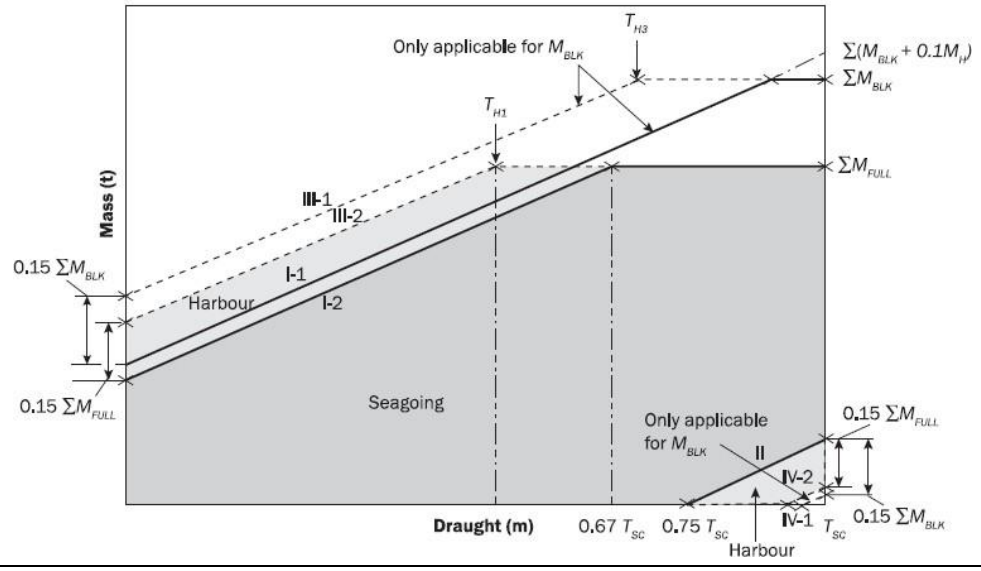
3.1.2 BC-A ships having {No MP} notation assigned

BC-A ship having {No MP} notation assigned **Table 6**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \max \begin{pmatrix} \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{Full} \end{pmatrix}$	I -1(1) I -2	Ch 4, Sec 8, [4.2.3] d Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}(T_i) = \max \begin{pmatrix} 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{BAL-H}) \ge 0 \\ 0.5\sum M_H - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \ge 0 \end{pmatrix}$	II -1 II -2	Ch 4, Sec 8, [4.2.2] c Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{pmatrix} W_{maxS}(T_i) + 0.15\sum M_{BLK} \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_{SC} - T_i) \le \sum M_{Full} \\ W_{maxS}(T_i) + 0.15\sum M_{Full} \le M_{Full} \end{pmatrix}$	III-1(1) III-2 III-3	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.6] b Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = \min \begin{pmatrix} W_{minS}(T_i) - 0.15\sum M_{BLK} \ge 0 \\ W_{minS}(T_i) - 0.15\sum M_{Full} \ge 0 \end{pmatrix}$	IV-1(1) IV-2	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.5]

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

Example BC-A ships not having {No MP} for two adjacent holds

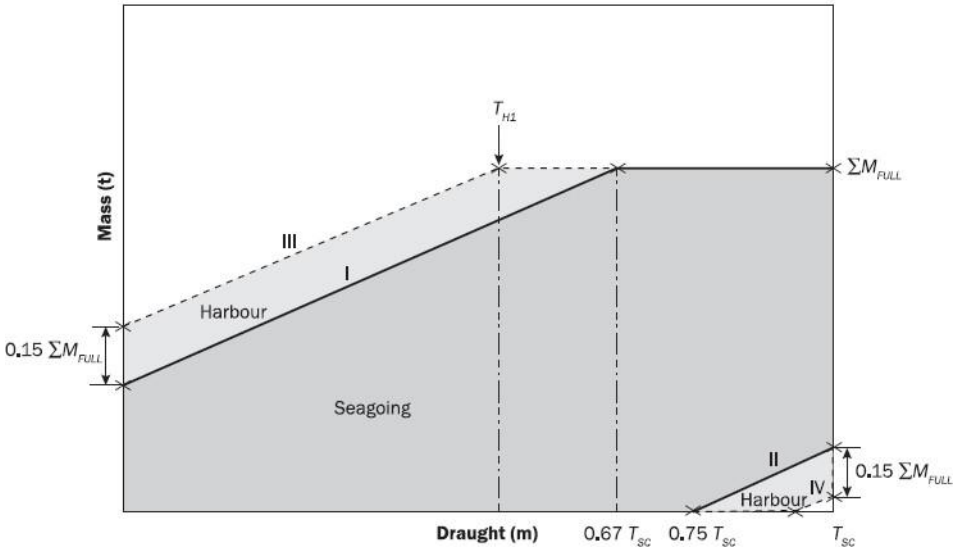


3.1.3 BC-B, BC-C ships, not having {No MP} notation assigned

BC-B and BC-C ships not having {No MP} notation assigned **Table 7**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \sum M_{Full} - 1.025 V_H \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67 T_{SC} - T_i) \leq M_{Full}$	I	Ch 4, Sec 8, [4.2.2] c
	Minimum: $W_{minS}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - 0.75 T_{SC}) \geq 0$	II	Ch 4, Sec 8, [4.2.2] d
Harbour	Maximum: $W_{maxH}(T_i) = W_{maxS}(T_i) + 0.15 \sum M_{Full} \leq \sum M_{Full}$	III	Ch4, Sec8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 \sum M_{Full} \geq 0$	IV	Ch4, Sec8, [4.2.5]

Example BC-B and BC-C ships not having {No MP} for two adjacent holds

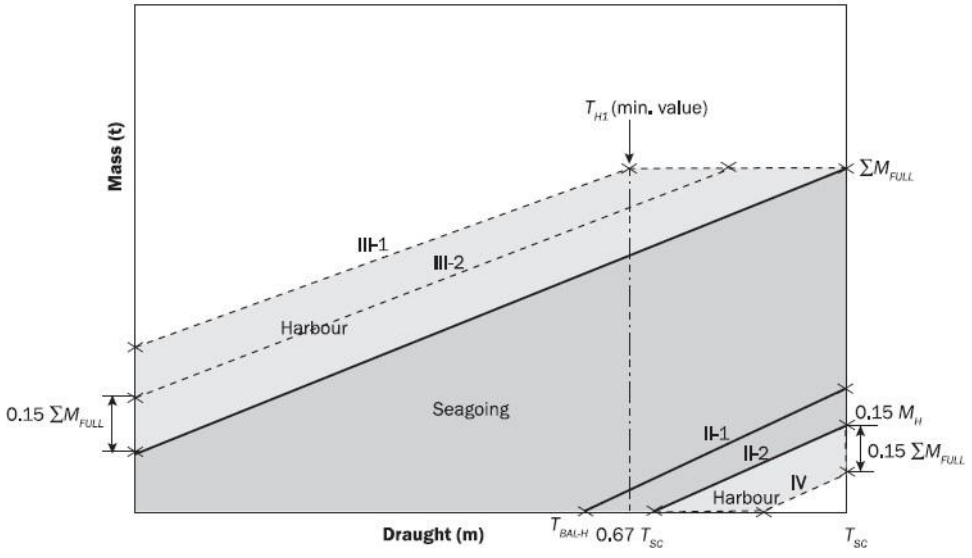


3.1.4 BC-B, BC-C ships, having {No MP} notation assigned

BC-B and BC-C ships having {No MP} notation assigned **Table 8**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \sum M_{Full} - 1.025 V_H \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_{SC} - T_i) \le M_{Full}$	I	Ch 4, Sec8, [4.2.1] a
	Minimum: $W_{minS}(T_i) = \max \begin{cases} 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - T_{BAL-H}) \ge 0 \\ 0.5 \sum M_H - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_{SC} - T_i) \ge 0 \end{cases}$	II -1 II -2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} \sum M_{Full} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67 T_{SC} - T_i) \le \sum M_{Full} \\ W_{maxS}(T_i) + 0.15 \sum M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 \sum M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships having {No MP} for two adjacent holds



Chapter 5 HULL GIRDER STRENGTH

Section 1 HULL GIRDER YIELDING STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p}$: Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

M_{wv} : Vertical wave bending moment in seagoing condition, in kNm, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.1.1].

M_{wh} : Horizontal wave bending moment, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [3.3.1].

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible positive or negative still water shear force for in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.2.1].

$Q_{sw\text{-}Lcd}$: Vertical still water shear force for the considered loading condition in seagoing operation, in kN, at the hull transverse section considered.

$Q_{sw\text{-}Lcd\text{-}p}$: Vertical still water shear force for the considered loading condition in harbour/sheltered operation, in kN, at the hull transverse section considered.

$Q_{sw\text{-}Lcd\text{-}f}$: Vertical still water shear force for the considered flooded condition in seagoing operation, in kN, at the hull transverse section considered.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch1, Sec 4, [3.6].

V_D : Vertical distance to the equivalent deck line, in m, as defined in [1.4.3].

z : Z coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch1, Sec 4, [3.6].

z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section with net scantling defined in [1.2], with respect to the reference coordinate system defined in Ch 1, Sec 4, [3.6].

$I_{y\text{-}n50}$: Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to [1.5].

$I_{z\text{-}n50}$: Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to [1.5].

$Z_{A\text{-}n50}$: Net section modulus, in m^3, at any point of the hull transverse section, to be calculated according [1.4.1].

$Z_{B\text{-}n50}$, $Z_{D\text{-}n50}$: Net section moduli, in m3, at bottom and deck, respectively, to be calculated according to [1.4.2] and [1.4.3].

z_{VD} : Z coordinate, in m, taken equal to $V_D + z_n$.

C_w : Wave parameter defined in Ch 4, Sec 4.

ρ : Seawater density, taken equal to 1.025 t/m^3.

f_β : Heading correction factor, to be taken as:

f_β = 1.05 for seagoing conditions.

f_β =1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

1 STRENGTH CHARACTERISTICS OF HULL GIRDER TRANSVERSE SECTIONS

1.1 General

1.1.1

This section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in [2] to [3], in association with the hull girder loads specified in Ch 4, Sec 4.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below and including the strength deck defined in [1.3], taking into account the requirements in [1.2.2] to [1.2.13].

1.2.2 Net scantling

The members contributing to the hull girder longitudinal strength are to be considered using the net offered scantlings based on gross offered thickness reduced by $0.5t_c$, as defined in Ch3, Sec3, when the hull girder strength characteristics are used for the hull girder yielding check according to [2] to [3].

1.2.3 Structural members not contributing to hull girder sectional area

The following members are not to be considered in the calculation as they are considered not contributing to the hull girder sectional area:

- Superstructures which do not form a strength deck.
- Deckhouses.
- Vertically corrugated bulkheads, according to [1.2.7].
- Bulwarks and gutter plates.
- Bilge keels.
- Sniped or non-continuous longitudinal stiffeners.
- Non-continuous hatch coaming.

1.2.4 Continuous trunks and longitudinal continuous hatch coamings

Continuous trunks and longitudinal continuous hatch coamings may be included in the hull girder transverse sections, provided that they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.5 Longitudinal stiffeners or girders welded above the strength deck

Longitudinal stiffeners or girders welded above the strength deck, including the deck of any trunk fitted as specified in [1.2.4], are to be included in the hull girder transverse sections.

1.2.6 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse section.

1.2.7 Longitudinal bulkheads with vertical corrugations

For longitudinal bulkheads with vertical corrugations, the vertical corrugations are not to be included in the hull girder transverse section. Longitudinal bulkheads with vertical corrugations are not effective for hull girder bending, but they are effective for hull girder shear force.

1.2.8 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus, E equal to 2.06×10^5 N/mm^2, the steel equivalent sectional area that may be included in hull girder transverse section is obtained, in m^2, from the following formula:

$$A_{SE-n50} = \frac{E}{2.06\times10^5} A_{M-n50}$$

where:

$A_{M\text{-}n50}$: Sectional area, in m^2, of the member under consideration.

1.2.9 Definitions of openings

The following definitions of opening are to be applied:

a) Large openings are:
   - Elliptical openings exceeding 2.5 m in length or 1.2 m in breadth.
   - Circular openings exceeding 0.9 m in diameter.

b) Small openings (i.e. drain holes, etc) are openings that are not large ones.

c) Manholes

d) solated openings are openings spaced not less than 1 m apart in the ship's transverse/vertical direction.

1.2.10 Large openings, manholes and nearby small openings

Large openings and manholes are to be deducted from the sectional area used in hull girder moment of inertia and section modulus. When small openings are spaced less than 1 m apart in the ship's transverse/vertical direction to large openings or manholes, the total breadth of them is to be deducted from the sectional area.

Additionally, isolated small openings which do not comply with the arrangement requirements given in Ch 3, Sec 6, [6.3.2] are to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.11 Isolated small openings

Isolated small openings in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\sum b_s \leq 0.06(B - \sum b)$$

Σb_S :Total breadth of isolated small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Figure 1, not deducted from the section area as per [1.2.10].

Σb :Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Figure 1, deducted from the section area as defined in [1.2.10].

Where the total breadth of isolated small openings Σb_s does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

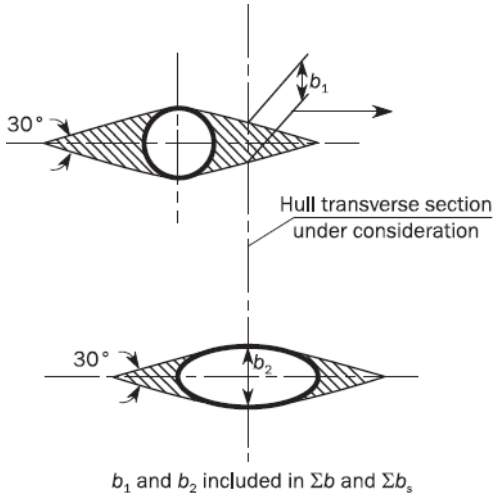


Figure 1 Calculation of Σb and Σb_s

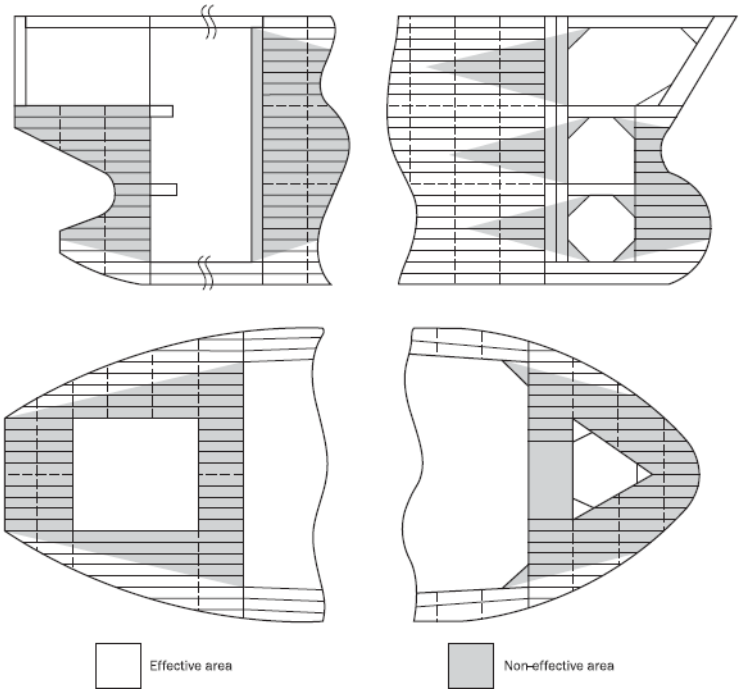


Figure 2 Effective area in way of non-continuous decks and bulkheads

1.2.12 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than $0.25h_w$, where h_w is the web height of the longitudinals, in mm. Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2.13 Non-continuous decks and longitudinal bulkheads

When calculating the effective area in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in Figure 2. The shadow area, which indicates the ineffective area, is obtained by drawing two tangent lines with an angle of 15 deg to the longitudinal axis of the ship.

1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck. In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.4 Section modulus

1.4.1 Section modulus at any point

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_{A-n50} = \frac{I_{y-n50}}{|Z - Z_n|}$$

1.4.2 Section modulus at bottom

The section modulus at bottom is obtained, in m^3, from the following formula:

$$Z_{B-n50} = \frac{I_{y-n50}}{Z_n}$$

1.4.3 Section modulus at deck

The section modulus at equivalent deck line is obtained, in m^3, from the following formula:

$$Z_{D-n50} = \frac{I_{y-n50}}{V_D}$$

where:

V_D : Vertical distance of the equivalent deck line, in m, taken equal to:

When no effective longitudinal members specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$V_D = z_D - z_n$

When effective longitudinal members as specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$$V_D = (z_T - z_n)\left(0.9 + 0.2\frac{y_T}{B}\right) \geq z_D - z_n$$

z_D : Z coordinate, in m, of strength deck at side, defined in [1.3].

y_T, z_T : Y and Z coordinates, in m, of the top of continuous trunk, hatch coaming, longitudinal stiffeners or girders, to be measured for the point which maximises the value of V_D.

1.5 Moments of inertia

1.5.1

The net moment of inertia, I_{y-n50} and I_{z-n50} in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [1.2].

2 HULL GIRDER BENDING ASSESSMENT

2.1 General

2.1.1

Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in [2.3] are to be maintained within 0.4L amidships.

2.1.2

The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [2.4] apply.

2.2 Normal stresses

2.2.1

The normal stress, σ_L induced by vertical bending moments, is to be assessed for both hogging and sagging conditions, along the full length of the hull girder, from AE to FE.

The normal stress, σ_L at any point of the hull transverse section located below z_{VD} is to comply with the following formula:

$$\sigma_L \leq \sigma_{perm}$$

where:

σ_L : Normal stress, in N/mm^2, as defined in [2.2.2].

σ_{perm} : Permissible hull girder bending stress, in N/mm^2, as given in Table 1.

2.2.2

The normal stresses, σ_L in N/mm^2, induced by vertical bending moments are given in Table 2.

2.2.3

The normal stresses in a member made in material other than steel with a Young's modulus, E equal to 2.06×10^5 N/mm^2, included in the hull girder transverse sections as specified in [1.2.8], are obtained from the following formula:

$$\sigma_L = \frac{E}{2.06\times10^5}\sigma_{Ls}$$

where:

σ_{LS} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.2.2] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.2.8].

Permissible hull girder bending stress **Table 1**

Operation	Design load	Permissible hull girder bending stress, σ_{perm}				
		$\frac{x}{L} \le 0.1$	$0.1 < \frac{x}{L} < 0.3$	$0.3 < \frac{x}{L} < 0.7$	$0.7 < \frac{x}{L} < 0.9$	$\frac{x}{L} \ge 0.9$
Seagoing	(S+D)	140/*k*	Linear interpolation	190/*k*	Linear interpolation	140/*k*
Harbour/ sheltered water	(S)	105/*k*	Linear interpolation	143/*k*	Linear interpolation	105/*k*
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	(A:S+D)	140/*k*	Linear interpolation	190/*k*	Linear interpolation	140/*k*

Normal stress, σ_L **Table 2**

Operation	Normal stress, σ_L		
	At any point located below Z_{VD}	At bottom (1)	At deck (1)
Seagoing	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{D-n50}} 10^{-3}$
Harbour/sheltered water	$\sigma_L = \frac{M_{sw-p}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{D-n50}} 10^{-3}$
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{D-n50}} 10^{-3}$
(1) The σ_L values at bottom and deck, correspond to the application of formula given for any point, calculated at equivalent deck line and at baseline.			

2.3 Minimum net moment of inertia and net section modulus at midship section

2.3.1

At the transverse section in the midship part, the net moment of inertia about the horizontal axis, $I_{y\text{-}n50}$ is to be not less than the value obtained, in m^4, from the following formula:

$$I_{yR} = 2.7 C_w L^3 B (C_b + 0.7) 10^{-8}$$

2.3.2

At the transverse section in the midship part, the vertical hull girder net section modulus at the deck and the bottom, $Z_{D\text{-}n50}$ and $Z_{B\text{-}n50}$, are not to be less than the value obtained, in m3, from the following formula:

$$Z_R = 0.9 k C_w L^2 B (C_b + 0.7) 10^{-6}$$

2.4 Extent of high tensile steel

2.4.1 Vertical extent

The vertical extent of higher strength steel, $z_{hts,i}$ in m, used in the deck zone or bottom zone and

measured respectively from the moulded deck line at side or baseline is not to be taken less the value obtained from the following formula, see Figure 3:

$$z_{hts,i} = z_1\left(1 - \frac{\sigma_{perm,i}}{\sigma_L}\right)$$

where:

z_1 : Distance from horizontal neutral axis to moulded deck line or baseline respectively, in m.

$\sigma_{perm,i}$: Permissible hull girder bending stress of the considered steel, in N/mm^2, as given in Table 1 and Figure 3.

σ_L : Hull girder bending stress, σ_{dk} at moulded deck line or σ_{bl} at baseline respectively, in N/mm^2 given in Table 3.

Hull girder stresses at baseline and moulded deck line **Table 3**

Operation	At baseline	At moulded deck line
Seagoing	$\sigma_{bl} = \frac{\lvert M_{sw} + f_\beta M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw} + f_\beta M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Harbour/sheltered water	$\sigma_{bl} = \frac{\lvert M_{sw-p}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw-p}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	$\sigma_{bl} = \frac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
z_{dk-s}: Distance from baseline to moulded deck line at side, in m.		

2.4.2 Longitudinal extent

Where used, the application of higher strength steel is to be continuous over the length of the ship to the location where the longitudinal stress levels are within the allowable range for mild steel structure, as shown in Figure 4.

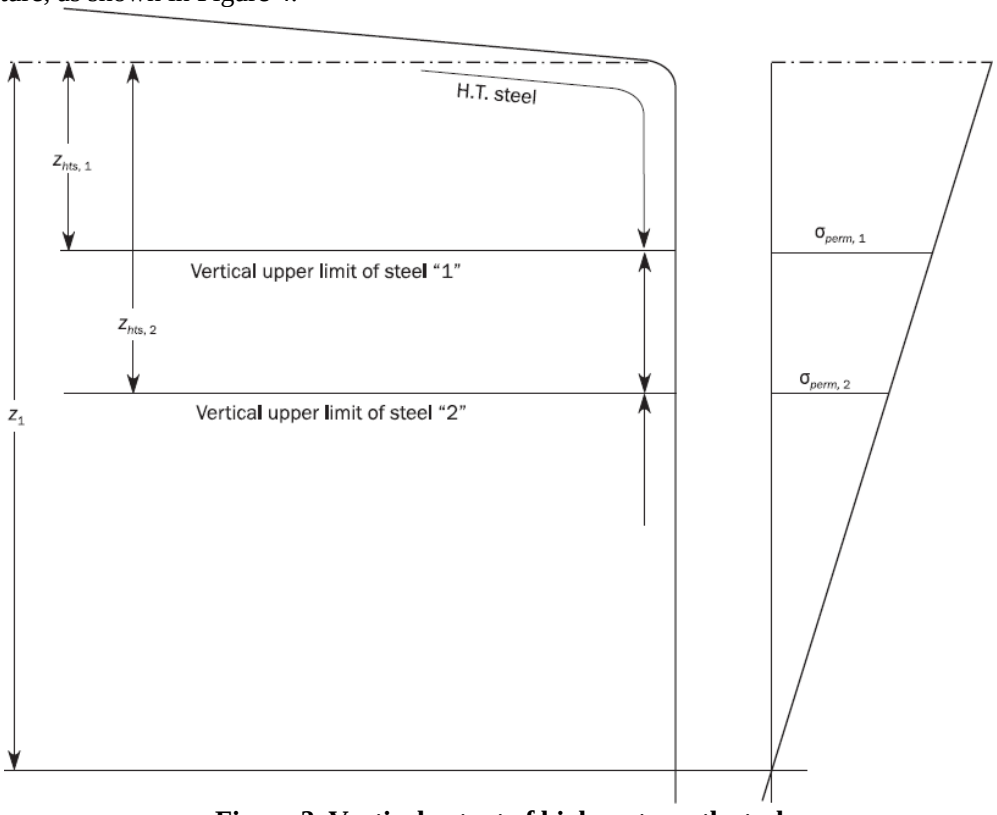


Figure 3 Vertical extent of higher strength steel

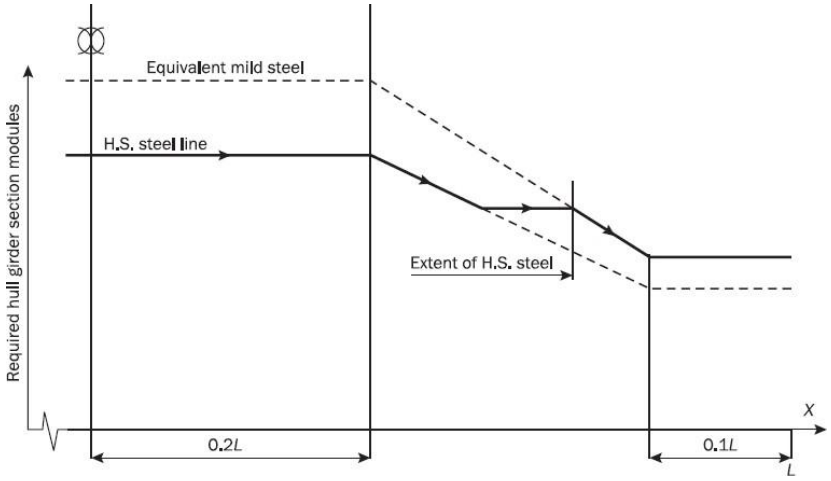


Figure 4 Longitudinal extent of higher strength steel

3 HULL GIRDER SHEAR STRENGTH ASSESSMENT

3.1 General

3.1.1

The hull girder shear strength requirements apply along the full length of the hull girder, from AE to FE.

3.2 Hull girder shear capacity

3.2.1

The total vertical hull girder shear capacity, Q_R in kN, is the minimum of the calculated values for all plates *i* contributing to the hull girder shear of the considered transverse section and is to be taken as:

$$Q_R = \min_i \left(\frac{\tau_{i-perm} \cdot t_{i-n50}}{q_{vi}} \cdot 10^{-3} \right)$$

where:

$t_{i\text{-}n50}$: Net thickness of plate *i*, in mm. For longitudinal bulkheads between cargo tanks of oil tankers, $t_{i\text{-}n50}$ is to be taken as $t_{sfi\text{-}n50}$ (see [3.4.1]) and $t_{sti\text{-}k\text{-}n50}$ (see [3.5.1]) as appropriate.

q_{vi} : Contribution ratio for hull girder shear force per mm, in mm^{-1}, for the plate *i* based on net scantlings with deduction of $0.5t_c$, which is equal to the unit shear flow per mm, in N/mm, obtained from a numerical calculation based on thin-walled beam theory according to Ch 5, App 1.

$\tau_{i\text{-}perm}$: Permissible shear stress, in N/mm^2, as given in Table 4, for plate *i*.

Permissible hull girder shear stress **Table 4**

Operation	Design load	Permissible hull girder shear, $\tau_{i\text{-}perm}$
Seagoing	(S+D)	120/k
Harbour/sheltered water	(S)	105/k
Flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above	(A:S+D)	120/k

3.3 Acceptance criteria

3.3.1 Permissible vertical shear force

The positive and negative permissible vertical shear forces are to comply with the following criteria:

- For seagoing operation:

$$|Q_{sw}| \le Q_R - |f_\beta Q_{wv}|$$

- For harbour/sheltered water operation:

$$|Q_{sw-p}| \le Q_R$$

- For flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above:

$$\left|Q_{sw-f}\right| \le Q_R - \left|Q_{wv}\right|$$

where:
Q_R : Total vertical hull girder shear capacity, in kN, as defined in [3.2.1].
The shear force Q_{wv}, used in 2 above criteria is to be taken with the same sign as the considered shear forces Q_{sw}, and Q_{sw-f} respectively.

3.3.2 Vertical still water shear force

The vertical still water shear forces, in kN, for all loading conditions are to comply with the following criteria:

- For seagoing operation:

$$\left|Q_{sw-Lcd} - \Delta Q_{mdf}\right| \le \left| Q_{sw}\right|$$

- For harbour/sheltered water operation:

$$\left|Q_{sw-Lcd-p} - \Delta Q_{mdf}\right| \le \left|Q_{sw-p}\right|$$

- For flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above:

$$\left|Q_{sw-Lcd-f} - \Delta Q_{mdf}\right| \le \left|Q_{sw-f}\right|$$

where:
ΔQ_{mdf} : Shear force correction at the transverse section considered, in kN, taken as:

- For bulk carriers, the value defined in [3.6.1].
- For oil tankers, $\Delta Q_{mdf} = 0$.

The permissible shear forces Q_{sw}, Q_{sw-p} and Q_{sw-f} are to be taken with the same sign as the considered shear forces Q_{sw-Lcd}, $Q_{sw-Lcd-p}$ and $Q_{sw-Lcd-f}$ respectively.

3.4 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers

3.4.1

For longitudinal bulkheads between cargo tanks, the effective net thickness of the plating above the inner bottom, $t_{sfi-n50}$ for plate i, in mm, is given by:

$$t_{sfi-n50} = t_{i-n50} - t_{\Delta i}$$

where:
$t_{\Delta i}$: Thickness deduction for plate i, in mm, as defined in [3.4.2].

3.4.2

The vertical distribution of thickness reduction for shear force correction is to be triangular as indicated in Figure 5. The thickness deduction, $t_{\Delta i}$ in mm, to account for shear force correction on the plate i, is to be taken as:

$$t_{\Delta i} = \frac{\delta Q_3}{h_{blk}\tau_{i-perm}}\left(1 - \frac{x_{blk}}{0.5 l_{tk}}\right)\left(2 - \frac{2\left(z_p - h_{db}\right)}{h_{blk}}\right)$$

where:
δQ_3 : Shear force correction for longitudinal bulkhead as defined in [3.4.3] and [3.4.4] for ships with one or two longitudinal bulkheads respectively, in kN.
l_{tk} : Length of cargo tank, in m.
h_{blk} : Height of longitudinal bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Figure 5.
x_{blk} : Minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in m. To be taken positive and not greater than $0.5 l_{tk}$.
z_p : Vertical distance from the lower edge of plate i to the base line, in m, but not taken less than h_{db}.
h_{db} : Height of double bottom, in m, as shown in Figure 5.
τ_{i-perm} : Permissible hull girder shear stress, in N/mm^2, for plate i:
$\tau_{i-perm} = 120/k$.

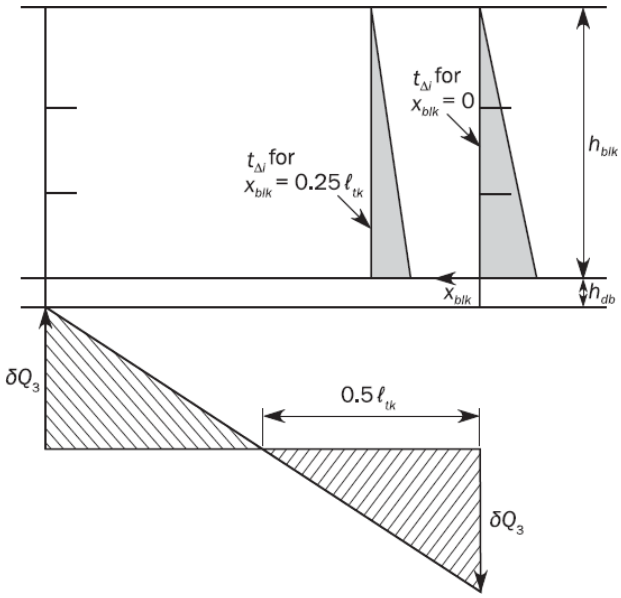


Figure 5 Shear force correction for longitudinal bulkheads

3.4.3 Shear force correction for a ship with a centreline longitudinal bulkhead

For ships with a centreline longitudinal bulkhead, the shear force correction in way of transverse bulkhead, δQ_3, in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5 K_3 F_{db}$$

where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.4 \cdot \left(1 - \frac{1}{1+n}\right) - f_3$$

n : Number of floors between transverse bulkheads.

f_3 : Shear force distribution factor, as defined in Table 7.

3.4.4 Shear force correction for a ship with two longitudinal bulkheads between the cargo tanks

For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3 in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5 K_3 F_{db}$$

where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.5 \cdot \left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3$$

where:

n : Number of floors between transverse bulkheads.

r : Ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side taken as

$$r = \frac{1}{\left[\dfrac{A_{3-n50}}{A_{1-n50} + A_{2-n50}} + \dfrac{2 \times 10^4 b_{80}\left(n_s + 1\right) A_{3-n50}}{l_{tk}\left(n_s A_{T-n50} + R\right)}\right]}$$

l_{tk} : Length of cargo tank, between transverse bulkheads in the side cargo tank, in m.

b_{80} : 80% of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in m, at tank mid length.

$A_{T\text{-}n50}$: Net shear area of the transverse wash bulkhead, including the double bottom floor directly

below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section.

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$:Net areas, as defined in Table 7, in m^2.

f_3 : Shear force distribution factor, as defined in Table 7.

n_S : Number of wash bulkheads in the side cargo tank.

R : Total efficiency of the transverse primary supporting members in the side tank in cm^2.

$$R = \left(\frac{n - n_s}{2} - 1 \right) \frac{A_{Q-n50}}{\gamma}$$

$$\gamma = 1 + \frac{300 b_{80}{}^2 A_{Q-n50}}{I_{psm-n50}}$$

$A_{Q\text{-}n50}$: Net shear area, in cm^2, of a transverse primary supporting member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. The net shear area is to be calculated at the mid span of the members.

$I_{psm\text{-}n50}$: Net moment of inertia for transverse primary supporting members, in cm^4, in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary supporting member spacing.

3.4.5 Vertical force on double bottom

The maximum vertical resulting force on the double bottom in a tank, F_{db} is in no case to be less than that given by the minimum conditions given in Table 5.

The maximum resulting force on the double bottom in a tank, F_{db} in kN, is to be taken as:

$$F_{db} = g \left| W_{CT} + W_{CWBT} - \rho b_2 l_{lk} T_{mean} \right|$$

where:

W_{CT} : Weight of cargo, in tonnes, as defined in Table 6.

W_{CWBT} : Weight of ballast, in tonnes, as defined in Table 6.

b_2 : Breadth, in m, as defined in Table 6.

l_{tk} : Length of cargo tank, in m.

T_{mean} : Draught at the mid length of the tank for the loading condition considered, in m.

Minimum conditions for double bottom **Table 5**

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ships with centreline bulkhead	Max positive net vertical force, F_{db+}	0.9 *Tsc* and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 *Tsc* and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db+}	0.9 *Tsc* and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 *Tsc* and full centre cargo tank and empty ballast tanks

Design conditions for double bottom **Table 6**

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ships with centreline bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast between port and starboard inner sides, in t.	Maximum breadth between port and starboard inner sides at mid length of tank, in m, as shown in Figure 6.
Ships with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast below the centre cargo tank, in t.	Maximum breadth of the centre cargo tank at mid length of tank, in m, as shown in Figure 6.

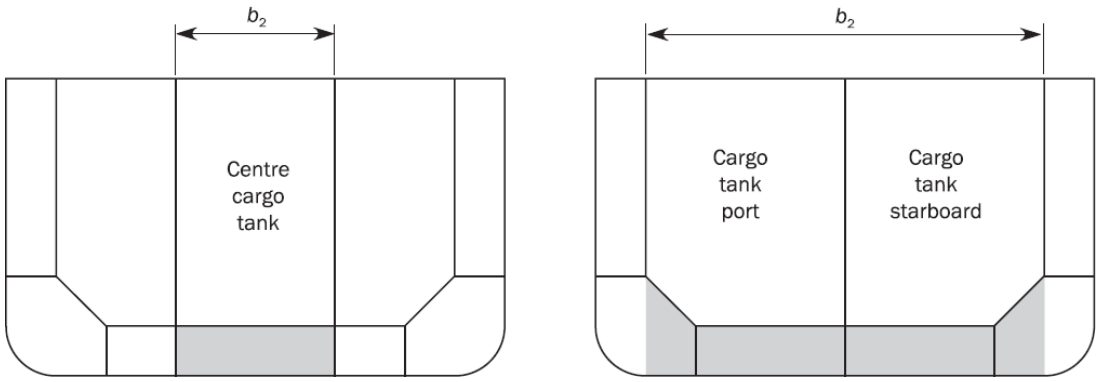
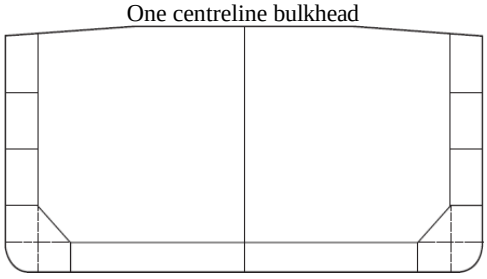
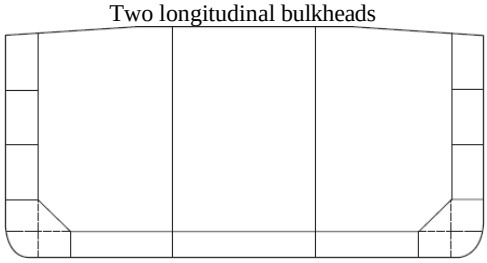


Figure 6 Tank breadth b_2

Shear force distribution factor for oil tanker **Table 7**

Hull configuration	f_3 factor
One centreline bulkhead 	$f_3 = 0.504 - 0.076\frac{A_{1-n50}}{A_{2-n50}} - 0.156\frac{A_{2-n50}}{A_{3-n50}}$
Two longitudinal bulkheads 	$f_3 = 0.353 - 0.049\frac{A_{1-n50}}{A_{2-n50}} - 0.095\frac{A_{2-n50}}{A_{3-n50}}$

where:

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$: Net projected area onto the vertical plane based on net thickness, t_{n50}, of the side shell, inner hull or the longitudinal bulkhead respectively, at one side of the section under consideration.

The area $A_{1\text{-}n50}$ includes the net plating area of the side shell, including the bilge.

The area $A_{2\text{-}n50}$ includes the net plating area of the inner hull, including the hopper side and the outboard girder under.

The Area $A_{3\text{-}n50}$ includes the net plating area of the longitudinal bulkheads, including the double bottom girders in line. The area $A_{3\text{-}n50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline. When the longitudinal bulkhead is made with corrugation, $A_{3\text{-}n50}$ is to consider the equivalent net thickness of the corrugation as defined in [3.4.6].

3.4.6 Equivalent net thickness of corrugation

The equivalent net thickness, in mm, of the corrugation of vertical and horizontal corrugated bulkheads, $t_{cor\text{-}n50}$, to be used for the calculation of the effective net shear area of $A_{3\text{-}n50}$ in Table 7 and for the unit shear flow, is given as follows:

$$t_{cor-n50} = \frac{t_{w-gr} + t_{f-gr}}{2} \cdot \frac{s_c}{c + a} - 0.5t_c$$

where:

$t_{w\text{-}gr}$: Gross corrugation web thickness, in mm.

$t_{f\text{-}gr}$: Gross corrugation flange thickness, in mm.

s_c : Projected length of one corrugation, in mm, as defined in Ch 3, Sec 6, Figure 21.

c : Breadth of corrugation web, in mm, as defined in Ch 3, Sec 6, Figure 21.
a : Breadth of corrugation flange, in mm, as defined in Ch 3, Sec 6, Figure 21.

3.5 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers-Correction due to loads from transverse bulkhead stringers

3.5.1

In way of transverse bulkhead stringer connections, within areas as specified in Figure 8, the equivalent net thickness of plate, $t_{sti\text{-}k\text{-}n50}$ in mm, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{sti-k-n50} = t_{sfi-n50}\left(1 - \frac{\tau_{sti-k}}{\tau_{i-perm}}\right)$$

where:

$\tau_{sti\text{-}k}$: Shear stress in plate i, in N/mm^2, in the longitudinal bulkhead due to the stringer force in way of stringer k, taken as:

$$\tau_{sti-k} = \frac{Q_{st-k}}{l_{st-k} t_{sfi-k-n50}}$$

$t_{sfi\text{-}k\text{-}n50}$: Effective net plating thickness as defined in [3.4.1], in mm, calculated at the transverse bulkhead for the height corresponding to the level of the stringer.

$t_{sfi\text{-}n50}$: Effective net plating thickness as defined in [3.4.1], calculated at the lower edge of plate i connecting to the stringer.

$\tau_{i\text{-}perm}$: permissible hull girder shear stress, in N/mm^2, for the plate i.

$\tau_{i\text{-}perm} = 120/k$

$l_{st\text{-}k}$: Connection length of stringer k, in m, as defined in Figure 7.

$Q_{st\text{-}k}$: Shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full in kN, taken as:

$$Q_{st-k} = 0.8F_{st-k}\left(1 - \frac{Z_{st-k} - h_{db}}{h_{blk}}\right)$$

$F_{st\text{-}k}$: Total stringer supporting force in way of a longitudinal bulkhead, in kN, taken as:

h_{db} : Double bottom height, in m.

h_{blk} : Height of bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead.

$z_{st\text{-}k}$: Z coordinate of the stringer k, in m.

$P_{st\text{-}k}$: Pressure on stringer k, in kN/m^2, taken as:

$$P_{st-k} = g\rho_L \cdot h_{tt-k}$$

ρ_L : Density of the liquid in cargo tank, in t/m^3, ad defined in Ch 4, Sec 6.

$h_{tt\text{-}k}$: Height from the top of the tank to the midpoint of the load area between $h_k/2$ below and $h_{k\text{-}1}/2$ above the stringer k, in m.

h_k : Vertical distance from the considered stringer k to the stringer k+1 below. For the lowermost stringer, it is to be taken as 80% of the average vertical distance to the inner bottom, in m.

$h_{k\text{-}1}$: Vertical distance from the considered stringer k to the stringer k-1 above. For the uppermost stringer, it is to be taken as 80% of the average vertical distance to the upper deck, in m.

$b_{st\text{-}k}$: Load breadth acting on stringer k, in m, as defined in Figure 9 and Figure 10.

3.5.2

Where reinforcement is provided to meet the above requirement, the reinforced area based on the maximum value of $t_{sti\text{-}k\text{-}n50}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area is to extend vertically from above the stringer level and down to 0.5 h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below is as defined in [3.5.1]. For the lowermost stringer the maximum plate thickness requirement, $t_{sti\text{-}k\text{-}n50}$ is to extend down to the inner bottom, see Figure 8.

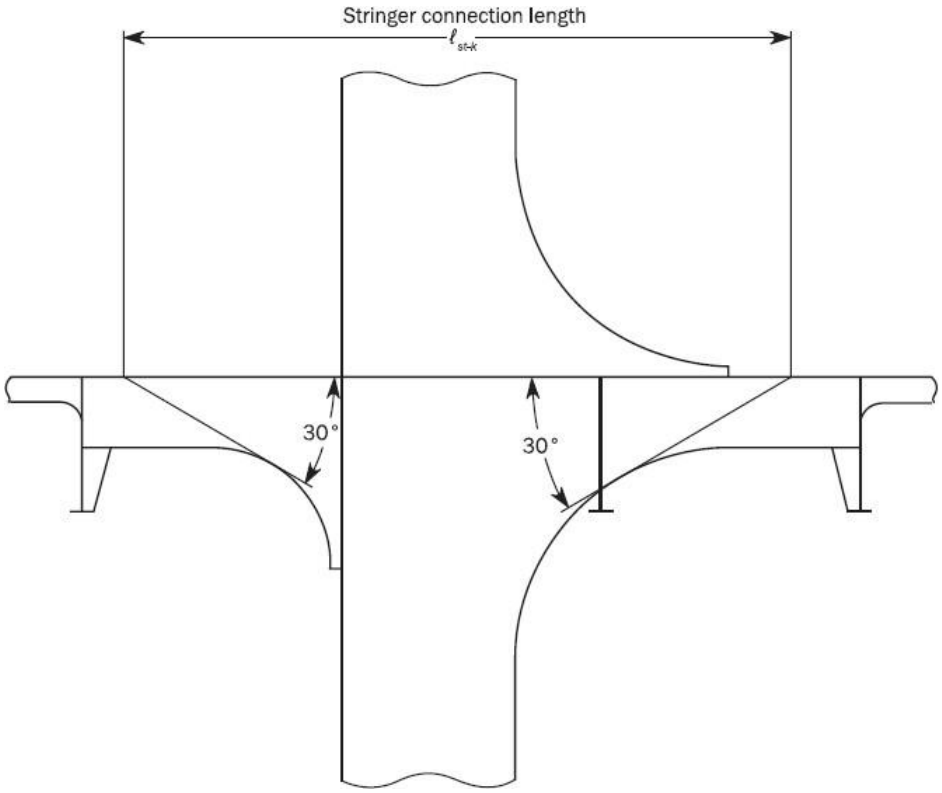


Figure 7 Effective connection length of stringer

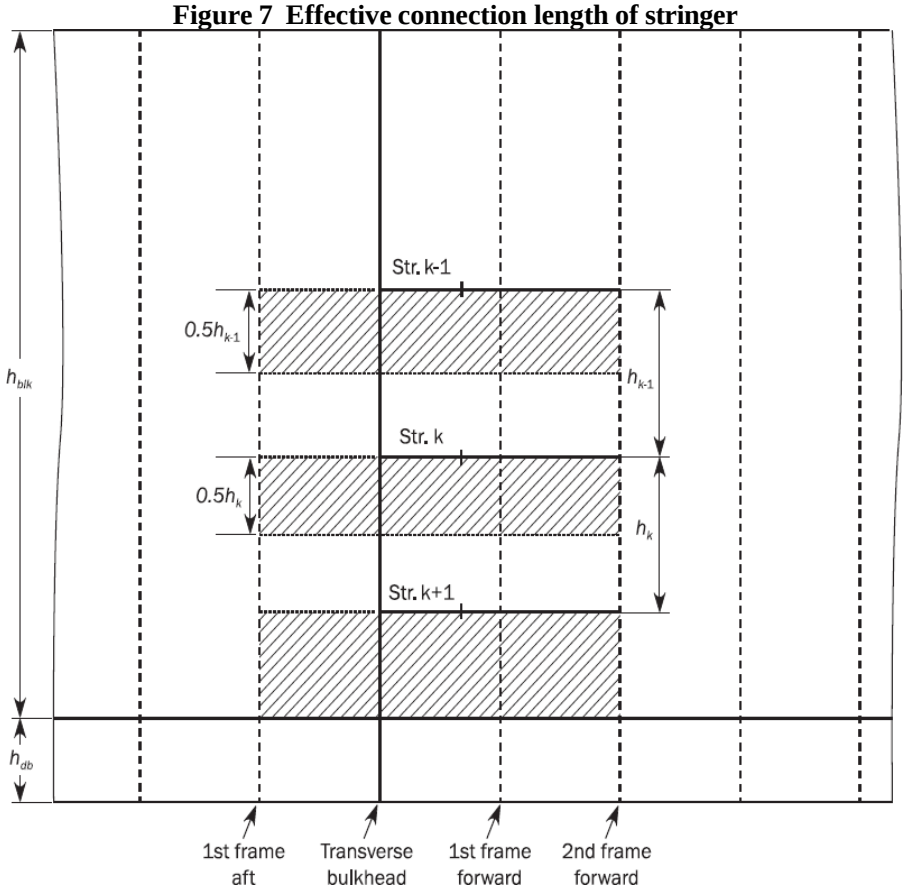


Figure 8 Region for stringer correction, t_i, for ships with 3 stringers

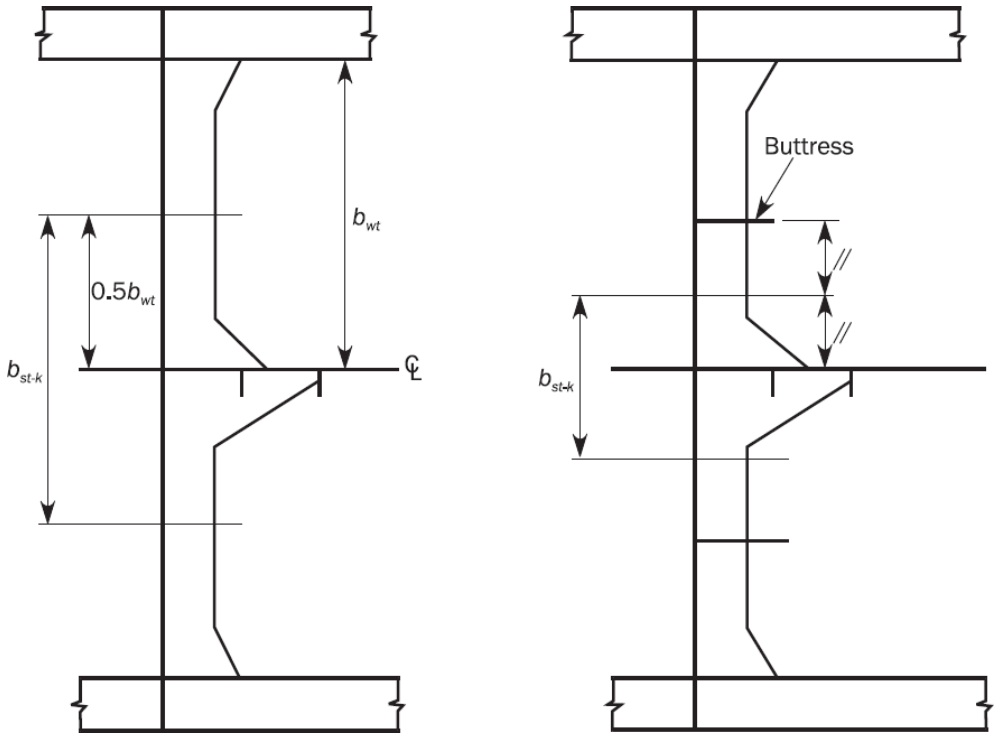


Figure 9 Load breadth of stringers for ships with a centreline bulkhead

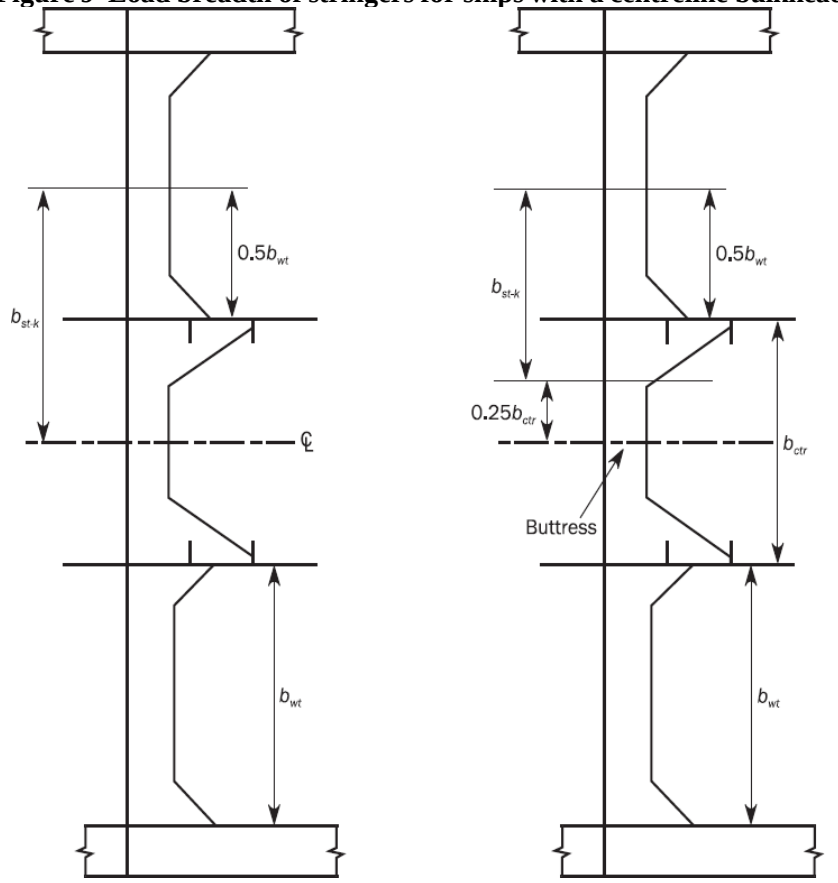


Figure 10 Load breadth of stringers for ships with 2 inner longitudinal bulkheads

In this figure:
b_{wt} is the breadth of wing cargo tank, in m.
b_{ctr} is the breadth of centre cargo tank, in m.

3.6 Shear force correction for bulk carriers

3.6.1

When hull girder shear strength assessment is performed in accordance with [3], shear force correction, which takes into account the portion of loads transmitted by the double bottom longitudinal girders to the transverse bulkheads, is to be considered.

For the considered cargo hold, the shear force correction at the considered transverse section is to be obtained, in kN, from the following formula:

$$\Delta Q_{mdf} = C_d \alpha \left(\frac{M}{B_H l_H} - \rho T_{LC,mh} \right)$$

where:

C_d : Distribution coefficient taken as:

- C_d = -1 at the aft end of the considered cargo hold except for aftmost cargo hold.
- C_d = 1 at the fore end of the considered cargo hold except for foremost cargo hold.
- C_d = 0 at mid-length of the cargo hold.
- C_d = 0 at the aft bulkhead of the aftmost cargo hold.
- C_d = 0 at the fore bulkhead of the foremost cargo hold.
- C_d: Linearly distributed at other locations.

α : Coefficient taken as:

$$\alpha = g \frac{l_0 b_0}{2 + \varphi \frac{l_0}{b_0}}$$

M : Mass, in t, in the hold in way of the considered transverse section for the considered loading condition. M is to include the mass of ballast water and fuel oil located directly below the flat portion of the inner bottom, if any, excluding the portion under the bulkhead stool.

B_H : Breadth of the cargo hold, in m, as defined in Ch 4, Sec 6.

l_H : Length of the cargo hold, in m, as defined in Ch 4, Sec 6.

l_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold.

$\varphi = 1.38 + 1.55 g \frac{l_0}{b_0}$, but not greater than 3.7

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.

ΔQ_{CF} : Shear force correction for the full hold.

ΔQ_{CE} : Shear force correction for the empty hold.

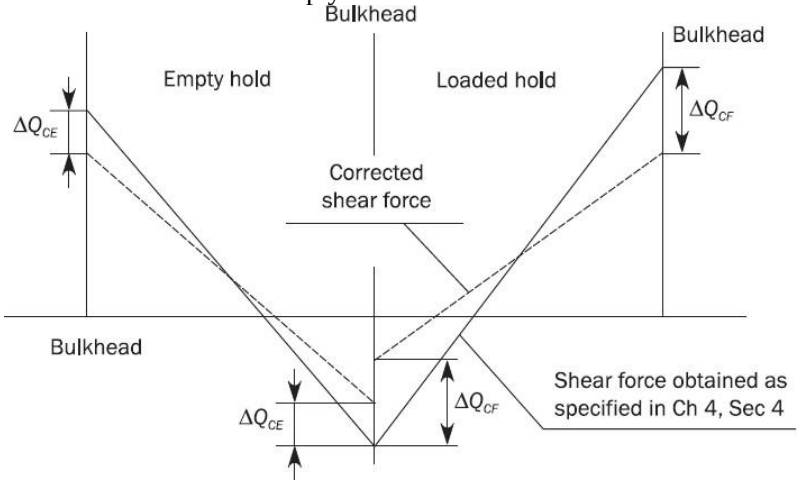


Figure 11 Shear force correction, ΔQ_C

Section 2 HULL GIRDER ULTIMATE STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

$M_{sw\text{-}h}$, $M_{sw\text{-}s}$: Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p\text{-}h}$, $M_{sw\text{-}p\text{-}s}$: Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships with freeboard length L_{LL} equal to or greater than 150 m.

1.1.2

The hull girder ultimate strength is to be assessed through the cargo hold region and machinery space.

1.1.3

The hull girder ultimate bending capacity is to be checked to ensure that it satisfies the checking criteria given in [2]. Such checking criteria are applicable to intact ship structures in the following conditions:

- For bulk carriers: seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: seagoing and harbour/sheltered water conditions.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity is to be checked for hogging and sagging conditions, for the following design load scenarios, as defined in Table 1:

- For bulk carriers: design load scenario A, for seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: design load scenario A, for seagoing and harbour/sheltered water conditions; and design load scenario B, for the operational seagoing homogeneous full load condition.

Design load scenarios **Table 1**

Design load scenarios		Permissible still water bending moment, $M_{sw\text{-}U}$
A	S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$
	S	$M_{sw\text{-}p\text{-}h}$ or $M_{sw\text{-}p\text{-}s}$
	A: S+D	$M_{sw\text{-}f}$
B	S+D	Maximum sagging still water bending moment for operational seagoing homogeneous full load condition (1)

(1) The maximum still water bending moment is to be taken from the departure condition with the ship homogeneously loaded at maximum draught and corresponding arrival and any mid-voyage conditions.

2.1.2

The vertical hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \leq \frac{M_U}{\gamma_R}$$

where:

M : Vertical bending moment, in kNm, to be obtained as specified in [2.2.1].

M_U : Vertical hull girder ultimate bending capacity, in kNm, to be obtained as specified in [2.3].

γ_R : Partial safety factor for the vertical hull girder ultimate bending capacity to be taken equal to:

$$\gamma_R = \gamma_M \gamma_{DB}$$

γ_M : Partial safety factor for the vertical hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties; in general, to be taken equal to:

$\gamma_M = 1.1$

γ_{DB} : Partial safety factor for the vertical hull girder ultimate bending capacity, covering the effect of double bottom bending, to be taken equal to:

- For hogging condition, except flooded conditions:
  - $\gamma_{DB} = 1.25$ for empty cargo holds in alternate condition of BC-A bulk carriers,
  - $\gamma_{DB} = 1.10$ for oil tankers, for BC-B and BC-C bulk carriers and loaded cargo holds in alternate condition of BC-A bulk carriers,
- For sagging condition, except flooded condition: $\gamma_{DB} = 1.0$
- For hogging and sagging condition, for flooded condition: $\gamma_{DB} = 1.0$

2.2 Hull girder ultimate bending loads

2.2.1

The vertical hull girder bending moment, M in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_s M_{sw-U} + \gamma_w f_\beta M_{wv}$$

where:

M_{sw-U}: Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Ch 4, Sec 4, [3.1].

γ_S : Partial safety factor for the still water bending moment, as defined in Table 2.

γ_W : Partial safety factor for the vertical wave bending moment, as defined in Table 2.

f_β : Heading correction factor, as defined in Sec 1.

Partial safety factors **Table 2**

Design load scenarios	γ_S	γ_W
A	1.0	1.2
B	1.0	1.3

2.3 Hull girder ultimate bending capacity

2.3.1

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity versus the curvature χ of the transverse section considered (see Figure 1). The curvature χ is positive for hogging condition and negative for sagging condition.

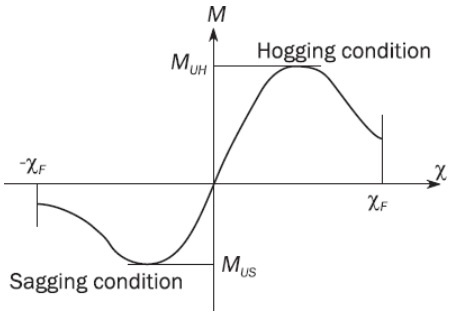


Figure 1 Bending moment capacity versus curvature χ

The hull girder ultimate bending capacity, M_U, is to be calculated according to Ch 5, App 2.

2.3.2
The effective area for the hull girder ultimate strength capacity assessment is specified in Ch 5, App 2.

Section 3 HULL GIRDER RESIDUAL STRENGTH

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships with freeboard length L_{LL} equal to or greater than 150 m.

1.1.2

The hull girder ultimate bending capacity in the damaged condition is to be checked for the seagoing condition to ensure that it satisfies the residual strength checking criteria given in [2].

1.1.3

The hull girder residual strength is to be assessed through the cargo hold region and the machinery space.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity in the damaged condition is to be checked for the damage conditions specified in [2.2] in hogging and sagging conditions. For the damage conditions specified in [2.2], for the design load scenario A, as defined in Table 1:

Design load scenarios **Table 1**

	Design load scenario	Permissible still water bending moment in damage, $M_{sw\text{-}D}$
Collision	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$
Grounding	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$

2.1.2

The vertical hull girder ultimate bending capacity in the damaged condition at any hull transverse section is to satisfy the following criteria:

$$M_D \leq \frac{M_{UD}}{\gamma_{RD} \cdot C_{NA}}$$

where:

M_D : Vertical bending moment in the damaged condition, in kNm, to be obtained as specified in [2.3].

M_{UD} : Vertical hull girder ultimate bending capacity in the damaged condition, in kNm, to be obtained as specified in [2.4].

γ_{RD} : Partial safety factor for the vertical hull girder ultimate bending capacity in the damaged condition, to be taken equal to:

$\gamma_{RD} = 1.0$

C_{NA} : Neutral axis coefficient taken as:

- $C_{NA} = 1.0$ for grounding,
- $C_{NA} = 1.1$ for collision.

2.2 Damage conditions

2.2.1 General

The damage conditions specified for collision in [2.2.2] and for grounding in [2.2.3] are to be considered. The damage extents specified in [2.2.2] and [2.2.3] are to be measured from the moulded lines of the ship.

Stiffener element is to be considered intact unless the connection of stiffener with attached plate is included in the damaged extent.

Plates and stiffeners of inner bottom and inner hull longitudinal bulkhead are to be considered intact unless the damage extent exceeds the moulded distance from inner bottom and inner hull longitudinal bulkhead plate respectively, to the hull envelope plate.

2.2.2 Collision

For the collision assessment of the considered transverse damage cross section, the damage is to be considered on one side and inclusive of the freeboard deck.

The damage for collision extends from the point of intersection of the moulded lines of deck and side:

- vertically downward for a distance *h* and upward without limit,
- transversally inboard for a distance *d* and outward without limit,

where *h* and *d* are given in Table 2 according to the side shell arrangement in the considered damage transverse section.

On ships with a rounded gunwale, the point of intersection is to be taken from the continuation of the moulded lines of deck and side.

Damage extent for collision **Table 2**

Damage penetration, in m	Side shell arrangement	
	Single side	Double side
Height, *h*	0.75 *D*	0.6*D*
Depth, *d*	*B*/16	*B*/16

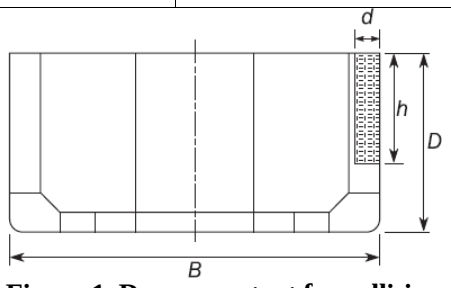


Figure 1 Damage extent for collision

The capacity of the damaged transverse cross section is calculated with the damage extent on one side, the ship kept in upright position.

2.2.3 Grounding

For the grounding assessment of the considered transverse damage cross section, the damage is to be considered on the bottom in the most unfavourable transversal position as regard to the structure considered by the damage.

The damage extent for grounding is given in Table 3.

Damage extent for grounding **Table 3**

Damage penetration, in m	Bulk carriers	Oil tankers
Height, *h*	Min (*B* /20, 2)	Min (*B* /15, 2)
Breadth, *b*	0.60 *B*	0.60 *B*

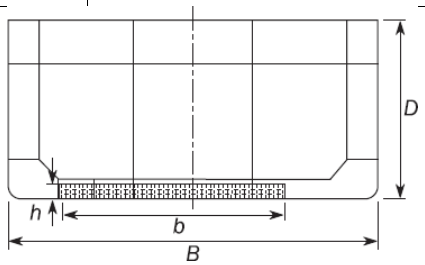


Figure 2 Damage extent for grounding

2.3 Hull girder ultimate bending loads in the damaged condition

2.3.1

The vertical bending moment, M_D in hogging and sagging conditions, to be considered in the ultimate strength check of the hull girder in the damaged condition, is to be obtained from the following formula:

$$M_D = \gamma_{SD} M_{sw-D} + \gamma_{WD} M_{wv}$$

where:

Ms_{w-D} : Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Ch 4, Sec 4, [3.1].

γ_{SD} : Partial safety factor for the still water bending moment in the damaged condition, to be taken equal to:

$\gamma_{SD} = 1.1$

γ_{WD} : Partial safety factor for the vertical wave bending moment in the damaged condition, to be taken equal to:

$\gamma_{WD} = 0.67$

2.4 Hull girder ultimate bending capacity in the damaged condition

2.4.1

The hull girder ultimate bending capacity in the damaged condition is to be calculated according to Ch 5, App 2, with the damaged parts assumed not to contribute to the hull girder strength. When assessing the ultimate bending capacity, M_{UD} of the damaged hull sections, damaged area as defined in [2.2] carries no loads and is to be removed in the capacity model.

2.4.2

The effective area of the intact partsfor the hull girder ultimate strength capacity assessment is specified in Ch 5 App 2.

Appendix 1 DIRECT CALCULATION OF SHEAR FLOW

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 CALCULATION FORMULA

1.1 General

1.1.1

This appendix describes the procedures of direct calculation of shear flow which is working along a ship cross section due to hull girder vertical shear force. Shear flow q_v, at each location in the cross section, is calculated where considering the cross section is subjected to a unit vertical shear force, 1 N, in the direction of z coordinate.

The unit shear flow per mm, q_v in N/mm, can be considered equal to:

$q_v = q_D + q_l$

where:

q_D : Determinate shear flow, as defined in [1.2].

q_l : Indeterminate shear flow which circulates around the closed cells, as defined in [1.3].

In the calculation of the unit shear flow, q_v, the longitudinal stiffeners are to be taken into account.

1.2 Determinate shear flow

1.2.1

The determinate shear flow, q_D in N/mm, at each location in the cross section can be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6 I_{y-n50}} \int_0^s (z - z_n) t_{n50} ds$$

where:

s : Coordinate value of running coordinate along the cross section, in m.

$I_{y\text{-}n50}$: Moment inertia of the cross section, in m^4.

t_{n50} : Net thickness of plating, in mm, or equivalent net thickness of corrugated plate as defined in Ch 5, Sec 1, [3.4.6].

1.2.2

Assuming the cross section is composed of line segments as shown in Figure 1, the determinate shear flow can be calculated by the following equation.

$$q_{Dk} = q_D(l) = -\frac{t_{n50} l}{2 \times 10^6 I_{y-n50}} (z_k + z_i - 2z_n) + q_{Di}$$

where:

q_{Dk}, q_{Di} : Determinate shear flow at node k and node i respectively, in N/mm.

l : Length of line segments, in m.

z_k, z_i : Z coordinate of the end point of line segment, in m, as defined in Figure 1.

1.2.3

Where the cross section includes closed cells, the closed cell are to be cut with virtual slits, as shown in Figure 2 in order to obtain the determinate shear flow.

However, the virtual slits must not be located at the walls by which the other closed cell is also bounded.

1.2.4

Calculations of the determinate shear flow at bifurcation points can be calculated such as water flow calculations as shown in Figure 2.

1.3 Indeterminate shear flow

1.3.1

The indeterminate shear flow is working around the closed cells and can be considered as a

constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ik}\oint_k \frac{1}{t_{n50}}ds - \sum_i q_{Ii}\oint_{k,i}\frac{1}{t_{n50}}ds = -\oint_k \frac{q_D}{t_{n50}}ds$$

q_{Ik}, q_{Ii} : Indeterminate shear flow around the closed cell k and i respectively, in N/mm.

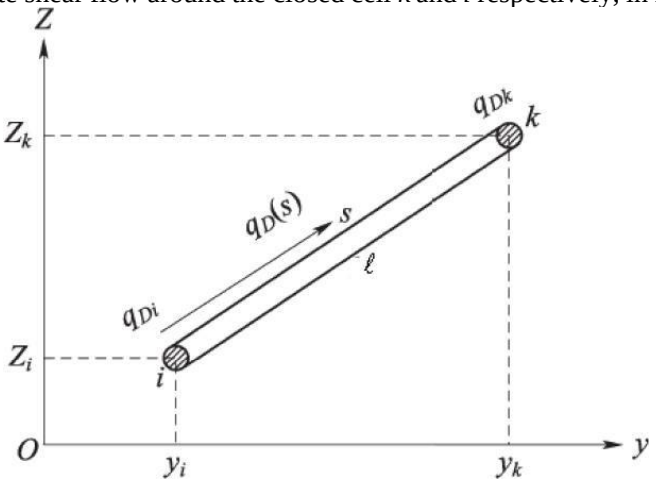


Figure 1 Definition of line segment

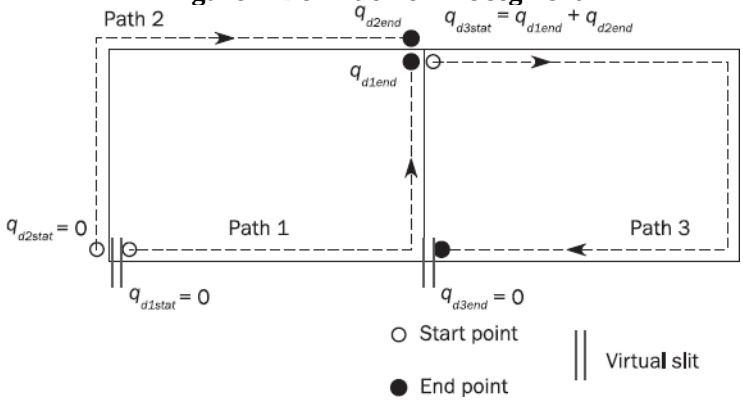


Figure 2 Calculation of determinate shear flow at bifurcation

1.3.2

With assuming assembly of line segments shown in Figure 1, the equations in [1.3.1] can be expressed as follows:

$$q_{Ik}\sum_{cell\ k}\frac{l}{t_{n50}} - \sum_i q_{Ii}\left(\frac{l}{t_{n50}}\right)\Bigg|_{common\ wall\ with\ cell\ k} = -\sum_{cell\ k}\phi$$

$$\phi = \int_0^l \frac{q_D(s)}{t_{n50}}ds = -\frac{l^2}{6\times10^3 I_{y-n50}}\left(z_k + 2z_i - 3z_G\right) + \frac{l}{t_{n50}}q_{Di}$$

q_{Di} : Determinate shear flow, in N/mm, calculated according to [1.2.2].

The difference in the directions of running coordinates specified in [1.2] and this sub-article is to be considered.

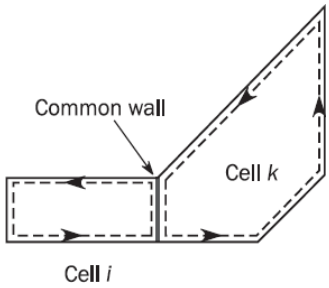


Figure 3 Closed cells and common wall

1.4 Computation of several properties of the cross section

1.4.1

Properties of the cross section can be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$l = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{n50} = 10^{-3} l t_{n50} \qquad A_{n50} = \sum a_{n50}$$

$$s_{y-n50} = \frac{a_{n50}}{2}(z_k + z_i) \qquad S_{y-n50} = \sum s_{y-n50}$$

$$i_{y0-n50} = \frac{a_{n50}}{3}(z_k^2 + z_k z_i + z_i^2) \qquad I_{y0-n50} = \sum i_{y0-n50}$$

where:

a_{n50}, A_{n50} : Area of the line segment and the cross section respectively, in m^2.
$s_{y\text{-}n50}$, $S_{y\text{-}n50}$: First moment of the line segment and the cross section about the baseline, in m^3.
$i_{y0\text{-}n50}$, $I_{y0\text{-}n50}$:Moment inertia of the line segment and the cross section about the baseline, in m^4.

1.4.2

The height of horizontal neutral axis, z_n in m, can be obtained as follows:

$$z_n = \frac{S_{y-n50}}{A_{n50}}$$

1.4.3

Inertia moment about the horizontal neutral axis, in m^4, can be calculated as follows:

$$I_{y-n50} = I_{y0-n50} - z_n^2 A_{n50}$$

2 EXAMPLE OF CALCULATIONS FOR A SINGLE SIDE HULL CROSS SECTION

2.1 Cross section data

2.1.1

The cross section is shown in Figure 4. The coordinates of the node points marked by filled black circles in Figure 4 are given in Table 1, where the plate thickness and the line segments (marked by circles in Figure 4) of the cross section are given in Table 2.

The sample calculations are performed taking advantage of symmetry of the cross section.

Node coordinates of cross section **Table 1**

Node number	*Y* coordinate (m)	*Z* coordinate (m)
0	0.00	0.00
1	5.80	0.00
2	11.70	0.00
3	14.42	0.00
4	16.13	1.72
5	16.13	6.11

Node number	*Y* coordinate (m)	*Z* coordinate (m)
6	11.70	1.68
7	5.80	1.68
8	0.00	1.68
9	16.13	14.15
10	16.13	19.60
11	7.50	20.25
12	7.50	19.63

Calculation of cross sectional properties **Table 2**

Line no.	Node *i*	Node *k*	Thickness (mm)	Length (m)	a_{n50} (m^2)	$s_{y\text{-}n50}$ (m^3)	$I_{y0\text{-}n50}$ (m^4)
1	0	1	17.0	5.80	0.099	0.000	0.00
2	1	2	17.0	5.90	0.100	0.000	0.00
3	2	3	17.0	2.72	0.046	0.000	0.00
4	3	4	17.0	2.43	0.041	0.035	0.04
5	4	5	18.0	4.39	0.079	0.309	1.34
6	5	6	19.0	6.26	0.119	0.464	2.00
7	6	7	21.0	5.90	0.124	0.208	0.35
8	7	8	21.0	5.80	0.122	0.205	0.34
9	5	9	18.0	8.04	0.145	1.466	15.63
10	9	10	21.0	5.45	0.114	1.931	32.87
11	10	11	24.0	8.65	0.208	4.139	82.47
12	11	12	24.0	0.62	0.015	0.297	5.92
13	12	9	15.0	10.22	0.153	2.590	44.13
14	2	6	15.0	1.68	0.025	0.021	0.02
15	1	7	15.0	1.68	0.025	0.021	0.02
				Total	1.416	11.686	185.138

2.1.2

The *Z* coordinate of horizontal neutral axis and the inertia moment about the neutral axis are calculated as follow:

$$z_n = \frac{\sum s_{y-n50}}{\sum a_{n50}} = \frac{11.686}{1.416} = 8.255$$

$$I_{y-n50} = 2\left(\sum i_{y0-n50} - z_n^2 \sum a_{n50}\right) = 2\left(185.138 - 8.255^2 \times 1.416\right) = 177.34$$

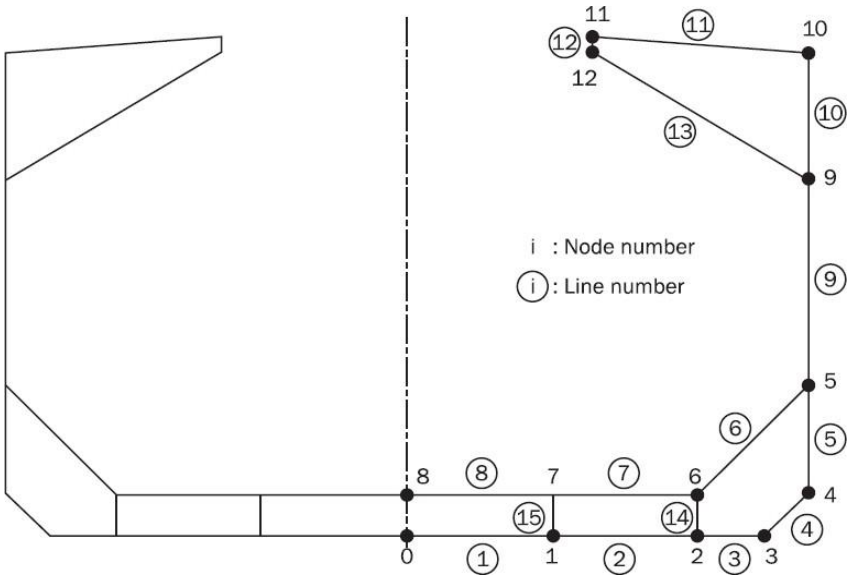


Figure 4 Numbering of nodes and lines

2.2 Calculations of the determinate shear flow

2.2.1

The virtual slits are added to cut the walls of the closed cells as shown in Figure 5. And then, the line integrations specified in [1.2.2] are performed to obtain determinate shear flow, q_D. The calculation results are shown in Table 3. The locations of the virtual slits and the paths of line integrations shown in Figure 5 are one such example. These definitions can be arbitrarily determined so as to calculate them easily.

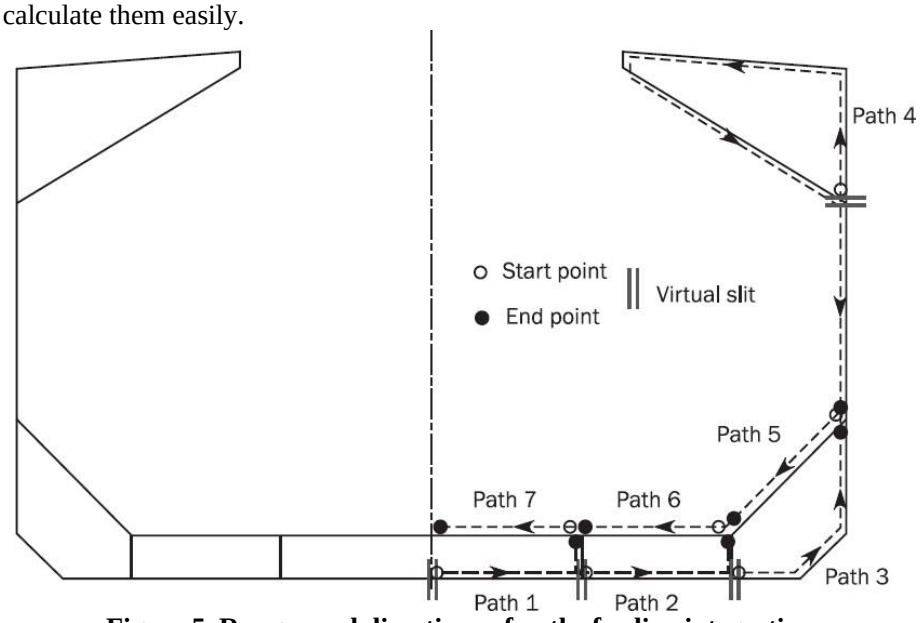


Figure 5 Ranges and directions of paths for line integrations

Calculation of determinate shear flow **Table 3**

	Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	$q_{Dk}\times10^{-6}$ (N/mm)	Note
1	1	0	1	0	4.6	Start from the virtual slit
	15	1	7	4.6	5.6	-
2	2	1	2	0	4.7	Start from the virtual slit
	14	2	6	4.7	5.7	-
3	3	2	3	0	2.2	Start from the virtual slit
	4	3	4	2.2	3.9	-

	Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	$q_{Dk}\times10^{-6}$ (N/mm)	Note
	5	4	5	3.9	5.8	-
4	10	9	10	0	-5.6	Start from the virtual slit
	11	10	11	-5.6	-19.2	-
	12	11	12	-19.2	-20.2	-
	13	12	9	-20.2	-27.7	-
	9	9	5	-27.7	-29.2	-
5	6	5	6	-23.4	-20.5	Start with the sum of q_{DK} at the ends of path 3 & 4
6	7	6	7	-14.8	-10.2	Start with the sum of q_{DK} at the ends of path 2 & 5
7	8	7	8	-4.5	0	Start with the sum of q_{DK} at the ends of path 1 & 6

2.3 Calculations of the indeterminate shear flow

2.3.1

To obtain the system of equations for indeterminate shear flows, the contour integrations around 3 closed cells as defined in Figure 6 are performed. The closed cell at the centre of double bottom is considered as an open shape since the symmetrical condition of the cross section is considered. The calculation results of contour integrations around the closed cells are shown in Table 4 to Table 6.

Contour integration of l/t_{n50} and ϕ around cell 1 **Table 4**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
2	1	2	0	347.1	0.81	-
14	2	6	4.7	112	0.58	Common wall with cell 2
7	6	7	-14.8	281	-3.5	-
15	7	1	-5.6	112	-0.58	-
			Total	852	-2.68	-

Contour integration of l/t_{n50} and ϕ around cell 2 **Table 5**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
3	2	3	0	160	0.17	-
4	3	4	2.2	142.7	0.43	-
5	4	5	3.9	243.9	1.22	-
6	5	6	-23.4	329.7	-7.32	-
14	6	2	-5.7	112	-0.58	Common wall with cell 1
			Total	988.3	-6.07	-

Contour integration of l/t_{n50} and ϕ around cell 3 **Table 6**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
10	9	10	0	259.5	-0.65	-
11	10	11	-5.6	360.6	-4.45	-
12	11	12	-19.2	25.8	-0.51	-
13	12	9	-20.2	681.5	-16.59	-
			Total	1327.5	-22.19	-

2.3.2

The following system of equations can be developed by using the results of the contour integration around each closed cell:

- Cell 1: 852.0 q_{I1} – 112.0 q_{I2} = 2.68 ×10^{-3}
- Cell 2: -112.0 q_{I1} + 988.3 q_{I2} = 6.07 ×10^{-3}
- Cell 3: 1327.5 q_{I3} = 2.219×10^{-2}

The solution of this system gives indeterminate shear flows of the closed cell 1 to 3:
q_{I1} = 4.01 ×10^{-6}, q_{I2} = 6.60 ×10^{-6}, q_{I3} = 1.67 ×10^{-5}

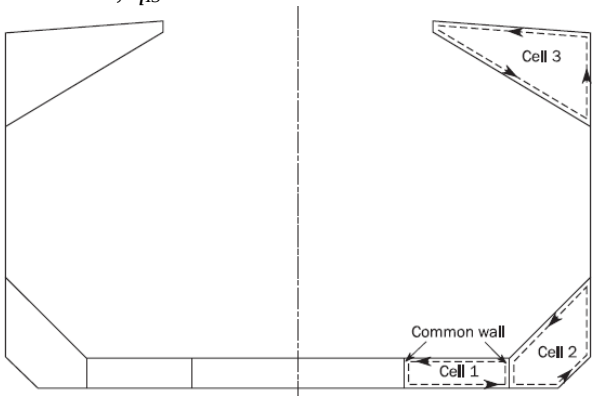


Figure 6 Numbering of closed cells

2.4 Summation

2.4.1

The shear flow q_v at all locations of the cross section can be obtained by the summation of determinate shear flow, q_D and indeterminate shear flow, q_I as shown in Figure 7.

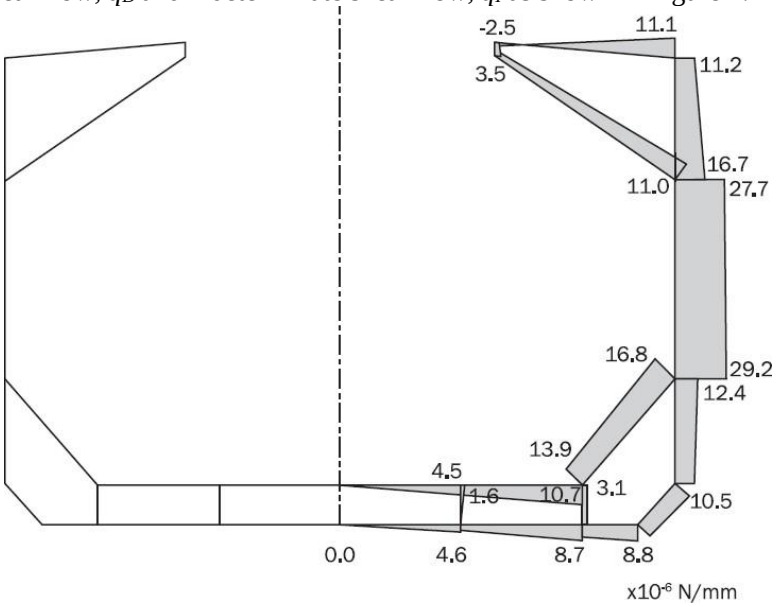


Figure 7 Calculation results of shear flow q_v, in 10^{-6} N/mm for vertical shear force with 1 N

Appendix 2 HULL GIRDER ULTIMATE CAPACITY

SYMBOLS

For symbols not defined in this article, refer to Ch 1, Sec 4.

$I_{y\text{-}n50}$: Moment of inertia, in m4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 1.

$Z_{B\text{-}n50}$, $Z_{D\text{-}n50}$: Section moduli, in m^3, at bottom and deck, respectively, defined in Ch 5, Sec 1.

R_{eHs} : Minimum yield stress, in N/mm^2, of the material of the considered stiffener.

R_{eHp} : Minimum yield stress, in N/mm^2, of the material of the considered plate.

$A_{s\text{-}n50}$: Net sectional area, in cm^2, of stiffener, without attached plating.

$A_{p\text{-}n50}$: Net sectional area, in cm^2, of attached plating.

z_i : z coordinate, in m, of centre of gravity of the i-th element.

1. GENERAL

1.1. Application

1.1.1

This appendix provides the criteria for obtaining the following ultimate longitudinal bending moment capacities:

1.1.1. M_U to be used in the hull girder ultimate capacity check according to Ch 5, Sec 2,

1.1.2. M_{UD} to be used in *the* hull girder residual strength capacity check according to Ch 5, Sec 3

1.1.2

The hull girder ultimate longitudinal bending moment capacity, M_U or M_{UD}, is defined as the maximum bending capacity of the hull girder beyond which the hull structure collapses. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.2. Methods

1.2.1. **Incremental-iterative method**

The hull girder ultimate bending capacity is to be assessed by the incremental-iterative method defined in [2].

1.2.2. **Alternative methods**

Principles for alternative methods for the calculation of the hull girder ultimate bending capacity; e.g. non- linear finite element analysis, are given in [3].

Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

1.3. Assumptions

1.3.1

The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.3.2

Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling; and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.3

Only vertical bending is considered. The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

1.3.4

For the calculation of the ultimate longitudinal bending moment capacity, M_{UD}, used in the hull girder residual strength check according to Ch 5, Sec 3, the structural members in way of the damage part are to be excluded from the members participating to the considered cross section strength.

2. INCREMENTAL-ITERATIVE METHOD

2.1. Assumptions

2.1.1

In applying the procedure described in [2.2], the following assumptions are generally to be made:

2.1.1. The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.

2.1.2. The hull girder transverse section remains plane during each curvature increment.

2.1.3. The hull material has an elasto-plastic behaviour.

2.1.4. The hull girder transverse section is divided into a set of elements, which are considered to act independently.

These elements are:

2.1.5. Transversely framed plating panels and/or stiffeners with attached plating, whose structural behaviour is described in [2.3.1].

2.1.6. Hard corners, constituted by plating crossing, whose structural behaviour is described in [2.3.2].

2.1.7. According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain, ε is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress, σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_{y\text{-}n50}}$$

where:

M_Y : Lesser of the values M_{Y1} and M_{Y2}, in kNm.

$M_{Y1} = 10^3 R_{eH} Z_{B\text{-}n50}$

$M_{Y2} = 10^3 R_{eH} Z_{D\text{-}n50}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2. Procedure

2.2.1. General

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Figure 1.

In this procedure, the ultimate hull girder bending moment capacity, M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Figure 1. The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step χ_{i-1}.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains, ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-

versa in sagging condition.
The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.
The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.
Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.
The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure1):

a) Step 1 : Divide the transverse section of hull into stiffened plate elements.
b) Step 2 : Define stress-strain relationships for all elements as shown in Table 1.
c) Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = 0.01 \frac{R_{eH}}{E} \frac{1}{z_D - z_n}$$

where:

z_D : Z coordinate, in m, of strength deck at side, with respect to reference coordinate defined in Ch 1, Sec 4, [3.6]

d) Step 4: Calculate for each element the corresponding strain, $\varepsilon_i = \chi(z_i - z_n)$ and the corresponding stress σ_i .
e) Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:
$\sum A_{i\text{-}n50}\sigma_i = \sum A_{j\text{-}n50}\sigma_j$ (*i*-th element is under compression, *j*-th element under tension).
f) Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_{i-n50} \left| \left(z_i - z_{NA_cur} \right) \right|$$

g) Step7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

2.2.2. Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength. The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.
The plate panel including web plate of girder or side stringer is idealised into either a stiffened plate element, an attached plate of a stiffener element or a hard corner element.

The plate panel is categorised into the following two kinds:

2.2.2.1. Longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
2.2.2.2. Transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

2.2.2.2.1. Hard corner element:

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding);

they are generally constituted by two plates not lying in the same plane.
The extent of a hard corner element from the point of intersection of the plates is taken equal to $20t_{n50}$ on transversely stiffened panel and to 0.5 s on a longitudinally stiffened panel, see Figure 2.
where:
t_{n50} : Net offered thickness of the plate, in mm.
s : Spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners. Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are not to be considered as a large girder so the attached plate/web connection is only considered as a hard corner, see Figure 3.

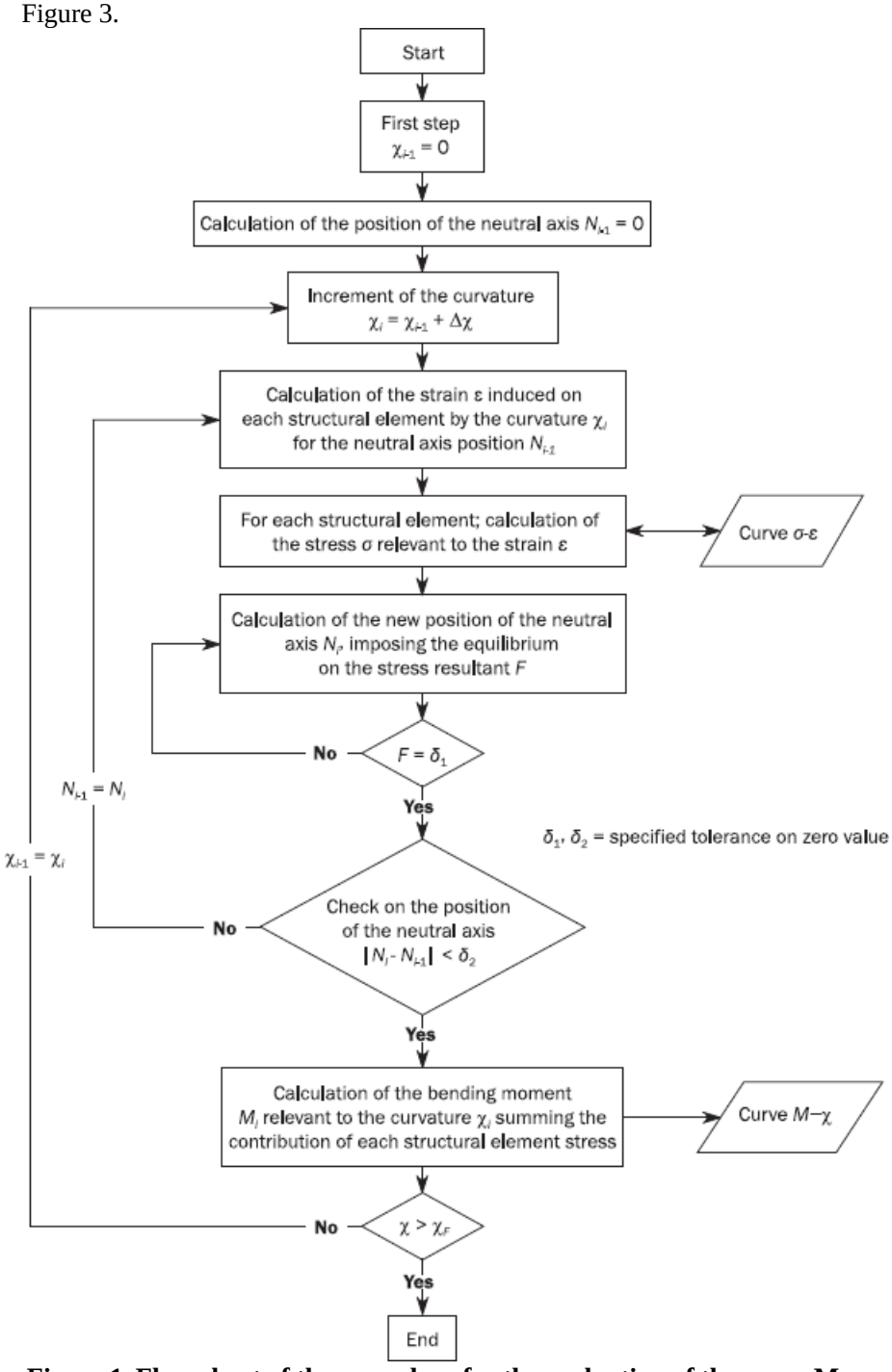


Figure 1 Flow chart of the procedure for the evaluation of the curve M-χ

2.2.2.2.2. Stiffener element:

The stiffener constitutes a stiffener element together with the attached plate. The attached plate width is in principle:

2.2.2.2.2.1. Equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or

2.2.2.2.2.2. Equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

2.2.2.2.3. Stiffened plate element:

The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

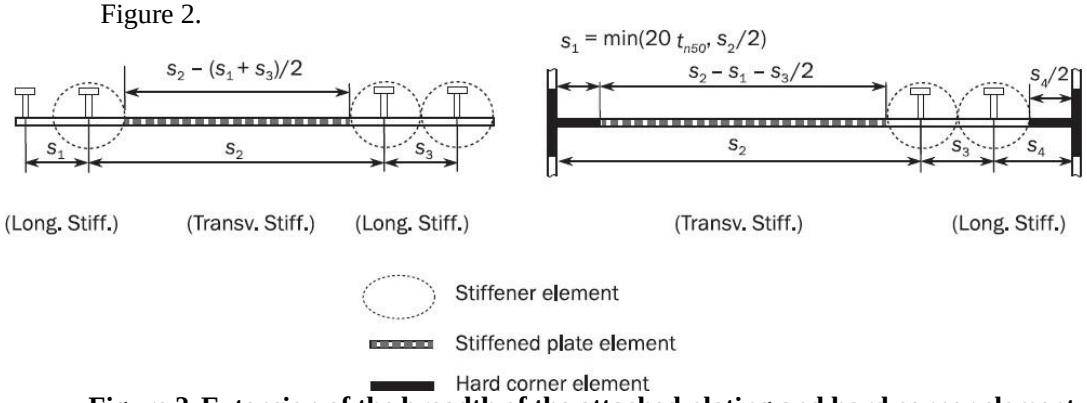


Figure 2 Extension of the breadth of the attached plating and hard corner element

The typical examples of modelling of hull girder section are illustrated in Figure 3 and Figure 4. Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch side girder.

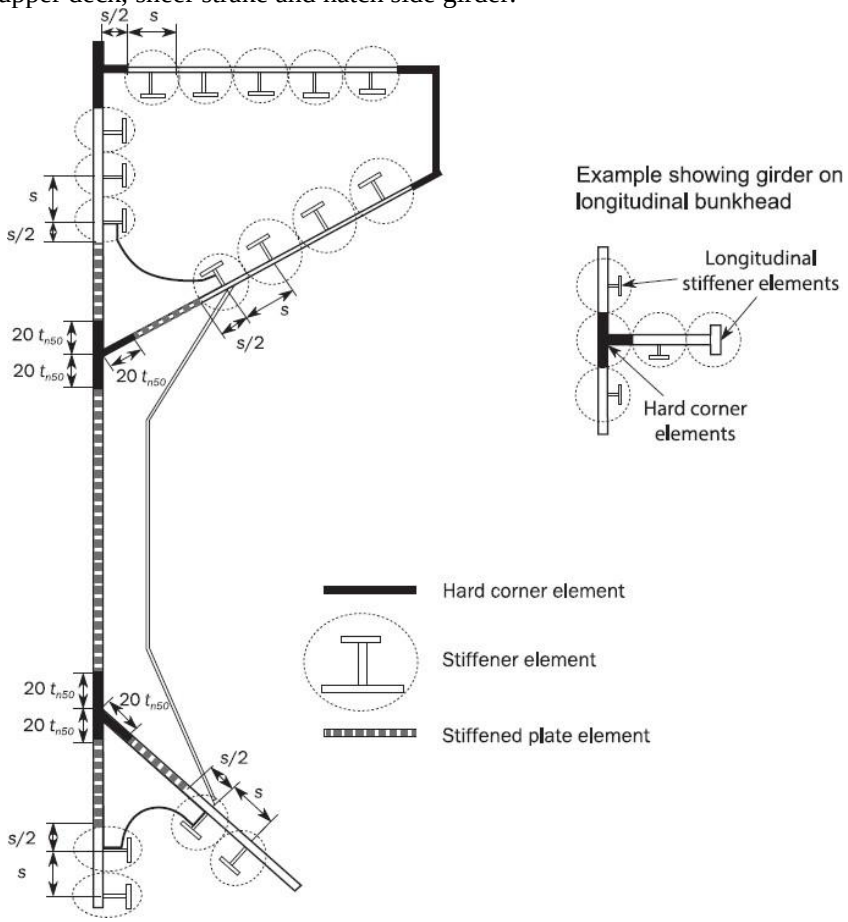


Figure 3 Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section

- In case of the knuckle point as shown in Figure 5, the plating area adjacent to knuckles in the plating with an angle greater than30 deg is defined as a hard corner. The extent of one side of the corner is taken equal to $20t_{n50}$ on transversely framed panels and to 0.5 *s* on longitudinally framed panels from the knuckle point.
- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.
- Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with Ch 5, Sec 1, [1.2.9].
- Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation.

$$t_{n50} = \frac{t_{1-n50}s_1 + t_{2-n50}s_2}{s} \quad R_{eHp} = \frac{R_{eHp1}t_{1-n50}s_1 + R_{eHp2}t_{2-n50}s_2}{t_{n50}s}$$

where R_{eHp1}, R_{eHp2}, $t_{1\text{-}n50}$, $t_{2\text{-}n50}$, s_1, s_2 and *s* are shown in Figure 6.

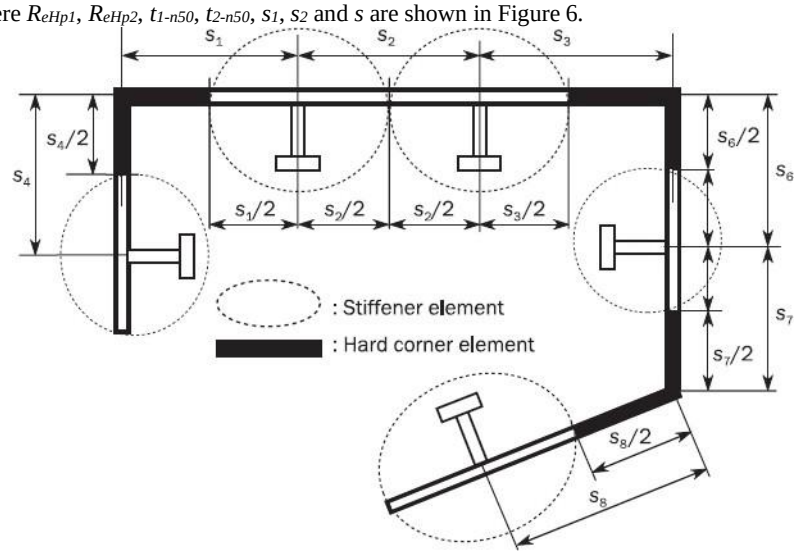


Figure 4 Extension of the breadth of the attached plating and hard corner element

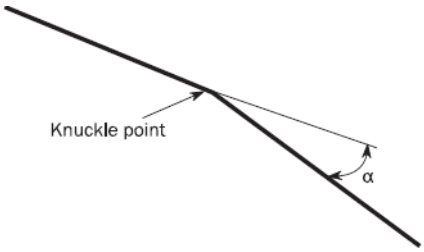


Figure 5 Plating with knuckle point

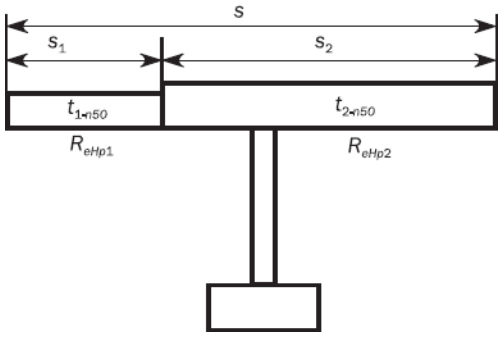


Figure 6 Element with different thickness and yield strength

2.3. Load-end shortening curves

2.3.1. Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may

collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.3.3] to [2.3.8], taking into account the non-continuous longitudinal stiffener. In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.
- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 5, Sec 1, [1.2.9] to Ch 5, Sec 1, [1.2.13].
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress- strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Modes of failure of stiffened plate element and stiffener element Table 1

Element	Mode of failure	Curve σ-ε defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	[2.3.3]
Shortened stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.3.4] [2.3.5] [2.3.6] [2.3.7]
Shortened stiffened plate element	Plate buckling	[2.3.8]

2.3.2. Hard corner element

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.3.3].

2.3.3. Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains, see Figure 7:

$$\sigma = \Phi R_{eHA}$$

where:

R_{eHA}: Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eHp} A_{p-50} + R_{eHs} A_{s-n50}}{A_{p-n50} + A_{s-n50}}$$

Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leqslant \varepsilon \leqslant 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain.

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

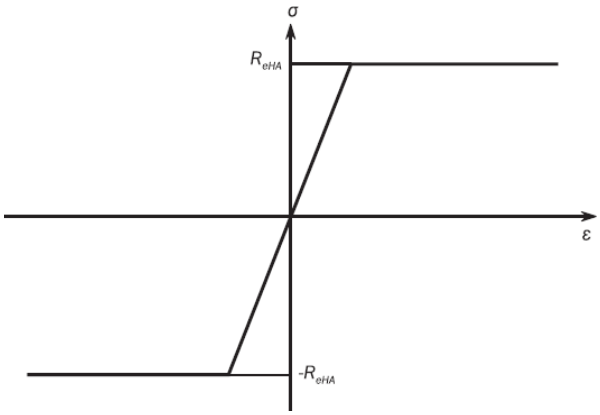


Figure 7 Load-end curve σ-ε for elasto plastic collapse

2.3.4. **Beam column buckling**

The equation describing the load-end shortening curve σ_{CR10}-ε for the beam column buckling of stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 8:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-n50} + A_{pE-n50}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C1} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for } \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

R_{eHB}: Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eHp}A_{pEI-n50}l_{pE} + R_{eHs}A_{s-n50}l_{sE}}{A_{pEI-n50}l_{pE} + A_{s-n50}l_{sE}}$$

$A_{pEl-n50}$: Effective area, in cm^2, equal to:

$A_{pEl-n50} = 10 b_{E1} t_{n50}$

l_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate.

l_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener.

ε : Relative strain, as defined in [2.3.3].

σ_{E1} : Euler column buckling stress, in N/mm^2, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-n50}}{A_{E-n50}l^2}10^{-4}$$

$I_{E\text{-}n50}$: Net moment of inertia of stiffeners, in cm^4, with attached plating of width b_{E1}.

$A_{E\text{-}n50}$: Net area, in cm^2, of stiffeners with attached plating of width b_E.

b_{E1} : Effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \qquad \text{for } \beta_E > 1.0$$

$$b_{E1} = s \qquad \text{for } \beta_E \le 1.0$$

β_E : $\beta_E = 10^3 \dfrac{s}{t_{n50}} \sqrt{\dfrac{\varepsilon R_{eHp}}{E}}$

$A_{pE\text{-}n50}$: Net sectional area, in cm^2, of attached plating of width b_E, equal to:

$$A_{pE-n50} = 10 b_E t_{n50}$$

b_E : Effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25$$

$$b_E = s \quad \text{for } \beta_E \le 1.25$$

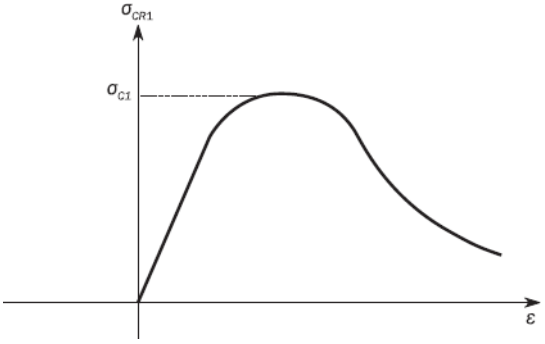


Figure 8 Load-end shortening curve σ_{CR1}-ε for beam column buckling

2.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula, see Figure 9.

$$\sigma_{CR2} = \Phi \frac{A_{s-n50}\sigma_{C2} + A_{p-n50}\sigma_{CP}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C2} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for } \sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm^2, taken as σ_{ET} in Ch 8, Sec 5, [2.3.4].

ε : Relative strain, as defined in [2.3.3].

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) R_{eHp} \quad \text{for} \quad \beta_E > 1.25$$

$$\sigma_{CP} = R_{eHp} \quad \text{for} \quad \beta_E \le 1.25$$

β_E : Coefficient, as defined in [2.3.4].

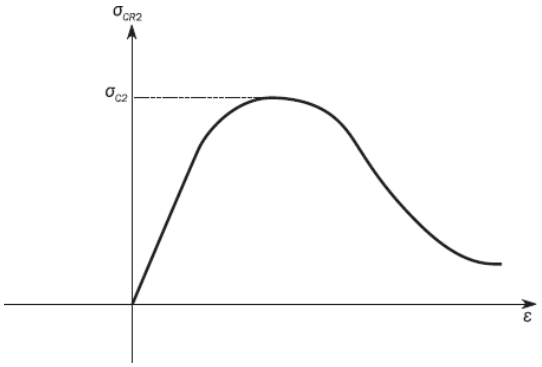


Figure 9 Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling

2.3.6 Web local buckling of stiffeners made of flanged profiles

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{n50} R_{eHp} + \left(h_{we} t_{w-n50} + b_f t_{f-n50}\right) R_{eHs}}{10^3 s t_{n50} + h_w t_{w-n50} + b_f t_{f-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].
b_E : Effective width, in m, of the attached shell plating, as defined in [2.3.4].
h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \quad \text{for} \quad \beta_w \geq 1.25$$
$$h_{we} = h_w \quad \text{for} \quad \beta_w < 1.25$$

ε : Relative strain, as defined in [2.3.3].

2.3.7 Web local buckling of stiffeners made of flat bars

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 10:

$$\sigma_{CR4} = \Phi \frac{A_{P-n50}\sigma_{CP} + A_{s-n50}\sigma_{C4}}{A_{p-n50} + A_{s-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].
σ_{CP} : Buckling stress of the attached plating, in N/mm^2, as defined in [2.3.5].
σ_{C4} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \leq \frac{R_{eHs}}{2}\varepsilon$$
$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm^2, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_{w-n50}}{h_w}\right)^2$$

ε : Relative strain, as defined in [2.3.3].

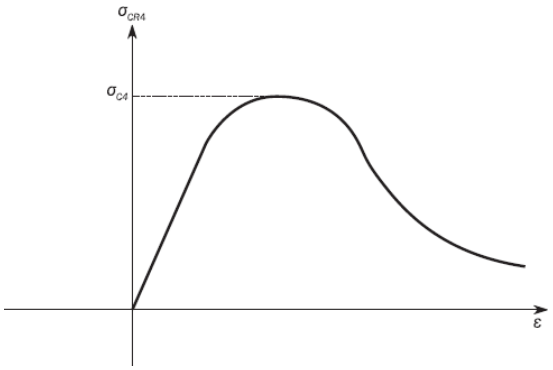


Figure 10 Load-end shortening curve σ_{CR4}-ε for web local buckling

2.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

where:

$$\sigma_{CR5} = \min\left\{ \begin{array}{c} R_{eHp}\Phi \\ \Phi R_{eHp}\left[\frac{s}{l}\left(\frac{2.25}{\beta_E}-\frac{1.25}{\beta_E^2}\right)+0.1\left(1-\frac{s}{l}\right)\left(1+\frac{1}{\beta_E^2}\right)^2\right] \end{array}\right.$$

Φ : Edge function, as defined in [2.3.3].

$$\beta_E : \beta_E = 10^3 \frac{s}{t_{n50}}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

s : Plate breadth, in m, taken as the spacing between the stiffeners.

l : Longer side of the plate, in m.

3. ALTERNATIVE METHODS

3.1. General

3.1.1

The bending moment-curvature relationship, M-χ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

a) Non-linear geometrical behaviour.
b) Inelastic material behaviour.
c) Geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners).
d) Simultaneously acting loads:
   - Bi-axial compression.
   - Bi-axial tension.
   - Shear and lateral pressure.
e) Boundary conditions.
f) Interactions between buckling modes.
g) Interactions between structural elements such as plates, stiffeners, girders, etc.
h) Post-buckling capacity.
i) Overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners etc (double bottom effects or similar).

3.2. Non-linear finite element analysis

3.2.1

Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in [3.1.1].

ISC 3.2.1a The non-linear finite element analysis method used for the assessment of the ultimate strength of hull girders are given in ISC Appendix C of this PART.

3.2.2

Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

Chapter 6 HULL LOCAL SCANTLING

Section 1 GENERAL

1 APPLICATION

1.1 Application

1.1.1

This chapter applies to hull structure over the full length of the ship including fore end, cargo hold region, machinery space and aft end, the side shell above the freeboard deck, engine casing, exposed decks of superstructure and internal decks except those inside superstructure and deckhouse.

1.1.2

This chapter provides requirements for evaluation of plating, stiffeners and Primary Supporting Members (PSM) subject to lateral pressure, local loads and to hull girder loads, as applicable. Requirements are specified for:

- Load application in Ch 6, Sec 2.
- Minimum thickness of plates, stiffeners and PSM in Ch 6, Sec 3.
- Plating in Ch 6, Sec 4.
- Stiffeners in Ch 6, Sec 5.
- PSM and pillars in Ch 6, Sec 6.

In addition, other requirements not related to defined design load sets, are provided.

1.1.3 Required scantlings

The offered net scantling is to be greater than or equal to the required scantlings based on requirements provided in this chapter.

1.1.4 Additional local strength requirements

Additional local strength requirements are provided in Ch 10 considering bow impact loads, bottom slamming loads and sloshing loads, and for fore end, machinery space and aft end.

1.2 Acceptance criteria

1.2.1

Acceptance criteria set to be selected based on design load as follows:

1.2.1 AC-S for design load S; static loads.

1.2.2 AC-SD for design load S+D; combination of static and dynamic loads.

Section 2 LOAD APPLICATION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 LOAD COMBINATION

1.1 Hull girder bending

1.1.1 Normal stresses

The normal stress σ_{hg} , in N/mm^2, induced by acting vertical and horizontal bending moments at the position being considered is given as follow. This stress is to be calculated for each design load set, as defined in [2] covering all dynamic load cases defined in Ch 4 in combination with M_{sw} both in hogging and in sagging.

$$\sigma_{hg} = \left(\frac{M_{sw} + M_{wv-LC}}{I_{y-n50}} (z - z_n) - \frac{M_{wh-LC}}{I_{z-n50}} y \right) 10^{-3}$$

where:

M_{sw} : Still water bending moment, in kNm, as defined in Ch 4, Sec 4, [2.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1.

$M_{wv\text{-}LC}$: Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

$M_{wh\text{-}LC}$: Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.4] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

$I_{y\text{-}n50}$: Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4.

$I_{z\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4.

y : Transverse coordinate of load calculation point, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

1.2 Lateral pressures

1.2.1 Static and dynamic pressures in intact conditions

The static and dynamic lateral pressures in intact condition induced by the sea and the various types of cargoes, ballast and other liquids are to be considered. Applied loads will depend on the location of the elements under consideration, and the adjacent type of compartments.

1.2.2 Lateral pressure in flooded conditions

Watertight boundaries of compartments not intended to carry liquids, excluding shell envelope, are to be subjected to lateral pressure in flooded conditions.

1.3 Pressure combination

1.3.1 Elements of the outer shell

If the compartment adjacent to the outer shell is intended to carry liquids, the static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding draught.

If the compartment adjacent to the outer shell is not intended to carry liquids, the internal pressures and external sea pressures are to be considered independently.

1.3.2 Elements other than those of the outer shell

Except as specified in [1.3.1], the static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.

2 DESIGN LOAD SETS

2.1 Application of load components

2.1.1 Application

These requirements apply to:

- Plating and stiffeners along the full length of the ship.
- PSM outside the cargo hold region.

2.1.2 Load components

The static and dynamic load components are to be determined in accordance with Ch 4, Sec 7, Table 1.

Radius of gyration, k_r, and metacentric height, GM, are to be in accordance with Ch 4, Sec 3, Table 1 and Ch 4, Sec 3, Table 2 for the considered loading conditions specified in the design load sets given in Table 1.

2.1.3 Design load sets for plating, stiffeners and PSM

Design load sets for plating, stiffeners and primary supporting members are given in Table 1.

In addition, the design load sets for primary supporting members of bulk carriers with freeboard length L_{LL} less than 150 m and of oil tankers within the cargo hold region are given respectively in Pt 2, Ch 1, Sec 4, [4.2] and in Pt 2, Ch 2, Sec 3, [1.2].

Design load sets **Table 1**

Item	Design load set	Load component	Draught	Design load	Loading condition
External shell and exposed deck	SEA-1	P_{ex}, P_D	T_{SC}	S+D	Full Load condition (1)
	SEA-2	P	T	S	Harbour condition (2)
Water ballast tank (oil tanker and bulk carrier)	WB-1	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition
	WB-2	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition Water ballast exchange
	WB-3	$P_{in} - P_{ex}$ (3)	$0.25T_{SC}$	S	Harbour/test condition
Water ballast tank (bulk carrier) and bulk cargo hold assigned as ballast hold	WB-4	$P_{in} - P_{ex}$ (3)	T_{BAL-H} (7)	S+D	Heavy ballast condition
	WB-5 (4)	$P_{in} - P_{ex}$ (3)	T_{BAL-H} (7)	S+D	Heavy ballast condition Water ballast exchange
	WB-6 (5)	P_{in}	-	S	Harbour/test condition
Cargo oil tank	OT-1	P_{in}	T_{SC}	S+D	Full Load condition
	OT-2	P_{in}	$0.6T_{SC}$	S+D	Partial load condition
	OT-3	P_{in}	-	S	Harbour/Test condition
Bulk cargo hold	BC-1	P_{in}	T_{SC}	S+D	Homogeneous loading, fully filled
	BC-2	P_{in}	-	S	
	BC-3	P_{in}	T_{SC}	S+D	Homogeneous heavy cargo, partially filled (BC-A, B ships)
	BC-4	P_{in}	-	S	
	BC-5	P_{in}	T_{SC}	S+D	Alternate light cargo, fully filled (BC-A ships)
	BC-6	P_{in}	-	S	
	BC-7	P_{in}	T_{SC}	S+D	Alternate heavy cargo, partially filled (BC-A ships.)
	BC-8	P_{in}	-	S	
Other tanks (fuel oil tank, fresh water tank)	TK-1	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ (3)	$0.25T_{SC}$	S	Harbour/test condition
Compartments not carrying liquids	FD-1 (6)	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2 (6)	P_{in}	-	S	Flooded condition
Exposed deck, internal decks or platforms	DL-1 (8)	P_{dl}, F_U	T_{SC}	S+D	Full Load condition
	DL-2 (8)	P_{dl}, F_U	-	S	Harbour condition

(1) For bulk carrier BC-A and BC-B, full load condition means 'homogeneous heavy cargo'.
(2) For external shell only.
(3) P_{ex} is to be considered for external shell only.
(4) Not to be applied to bulk cargo hold assigned as ballast hold.
(5) Bulk cargo hold only.
(6) FD-1 and FD-2 are not applicable to external shell and corrugations of transverse vertically corrugated bulkhead separating cargo holds. Requirement in flooded conditions of transverse corrugated bulkhead are given in Pt 2, Ch 1, Sec 3, [3]. FD-1 and FD-2 are to be considered for strength deck whenever applicable.
(7) Minimum draught among heavy ballast conditions is to be used.
(8) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure.

Section 3 MINIMUM THICKNESSES

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 PLATING

1.1 Minimum thickness requirements

1.1.1
The net thickness of plating in mm, is to comply with the appropriate minimum thickness requirements given in Table 1.

Minimum net thickness for plating **Table 1**

Element	Location	Area	Net thickness
Shell	Keel	-	$7.5 + 0.03\,L_2$
	Bottom Side shell Bilge	Fore Part	$6.5 + 0.03\,L_2$
		Machinery space Aft part	$7.0 + 0.03\,L_2$
		Elsewhere	$5.5 + 0.03\,L_2$
Breasthook	Fore part	Breasthook	6.5
Deck	Weather deck, strength deck, internal tank boundary	-	$4.5 + 0.02\,L_2$
	Platform deck	Machinery space	$2.8 + 0.0067s$
		Elsewhere	6.5
Inner bottom (1)	-	Machinery space	$6.6 + 0.024\,L_2$
		Elsewhere	$5.5 + 0.03\,L_2$
Longitudinal bulkheads of bulk carriers	Inner side, hopper tank top, top wing tank longitudinal bulkhead	Cargo hold region	$0.7\,L_2$
Bulkheads	Internal tank boundary, Transverse/longitudinal watertight bulkhead	-	$4.5 + 0.02\,L_2$
	Non-tight bulkhead, Wash bulkhead, Bulkheads between dry spaces.	-	$4.5 + 0.01\,L_2$
	Pillar bulkheads in fore and aft peaks	-	7.5
Other members	Diaphragms in lower/upper stool	-	$5.0 + 0.015\,L_2$
	Engine casing (in the cargo hold region)	Cargo hold region	5.5
	Engine casing (in way of accommodation)	Accommodation	4.0
	Other plates in general	-	$4.5 + 0.01L_2$
(1) Applicable for both tight and non tight members			

2 STIFFENERS AND TRIPPING BRACKETS

2.1 Minimum thickness requirements

2.1.1
The net thickness of the web and face plate, if any, of stiffeners and tripping brackets in mm, is to comply with the minimum net thickness given in Table 2.

In addition, the net thickness of the web of stiffeners and tripping brackets, in mm, is to be:

- Not less than 40% of the net required thickness of the attached plating, to be determined

according to Ch 6, Sec 4.

- Less than twice the net offered thickness of the attached plating.

Minimum net thickness for stiffeners and tripping brackets **Table 2**

Element	Location	Net thickness
Stiffeners and attached end brackets	Watertight boundary	3.5 + 0.015 L_2
	Other structure	3.0 + 0.015 L_2
Cargo hold side frames webs of single side bulk carriers	Foremost hold (1)	6.0 + 0.026 L
	Other holds (1)	5.2 + 0.023 L
Tripping brackets		5.0+ 0.015 L_2
(1) L needs not to be taken greater than 200 m		

3 PRIMARY SUPPORTING MEMBERS

3.1 Minimum thickness requirements

3.1.1

The net thickness of web plating and flange of primary supporting members in mm, is to comply with the minimum net thickness given in Table 3.

Minimum net thickness for primary supporting members **Table 3**

Element	Location		Net thickness
Double bottom centreline girder	Machinery space		1.55 $L_2^{1/3}$+3.5
	Elsewhere		5.5 + 0.025 L_2
Other bottom girder	Machinery space		1.7 $L_2^{1/3}$+1.0
	Fore part of ships with $L \geqslant$ 150 m		0.7 $L_2^{1/2}$
	Elsewhere and fore part of ships with L < 150 m		5.5 + 0.02 L_2
Girders bounding a duct keel	Machinery space		0.8 $L_2^{1/2}$ + 2.5
Bottom floor	Machinery space		1.7 $L_2^{1/3}$ + 1.0
	Fore part		0.7 $L_2^{1/2}$
	Elsewhere		0.6 $L_2^{1/2}$
Aft peak floor	-		0.7 $L_2^{1/2}$
Other primary supporting member	Aft part / fore part		0.7 $L_2^{1/2}$
	Elsewhere	In oil cargo tanks	5.5+0.015L_2
		For other cases	0.6 $L_2^{1/2}$

Section 4 PLATING

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as follow but not to be taken greater than 1.0.

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

P : Design pressure for the considered design load set, see Ch 6, Sec 2, [2], calculated at the load calculation point defined in Ch 3, Sec 7, [2.2], in kN/m^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [2.2].

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.70 for inner bottom and bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition:
  - χ= 1.00 for collision bulkheads for acceptance criteria set AC-S,
  - χ= 0.95 for collision bulkheads for acceptance criteria set AC-SD,
  - χ= 1.15 for other watertight boundaries of compartments.

1 PLATING SUBJECTED TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Plating

The net thickness, t in mm, is not to be taken less than the greatest value for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{\chi C_a R_{eH}}}$$

C_a : Permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta - \alpha\frac{|\sigma_{hg}|}{R_{eH}} \text{ not to be taken greater than } C_{a\text{-}max}.$$

β : Coefficient as defined in Table 1.

α : Coefficient as defined in Table 1.

$C_{a\text{-}max}$: Maximum permissible bending stress coefficient as defined in Table 1.

Definition β, α and $C_{a\text{-}max}$ **Table 1**

Acceptance criteria set	Structural member		β	α	$C_{a\text{-}max}$
AC-S	Longitudinal strength members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely stiffened plating	0.9	1.0	0.8
	Other members		0.8	0.8	0
AC-SD	Longitudinal strength members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely stiffened plating	1.05	1.0	0.95
	Other members		1.0	1.0	0

1.2 Plating of corrugated bulkheads

1.2.1 Cold hot formed and built up corrugations

The net thicknesses, t in mm, of the web and flange plates of corrugated bulkheads are not to be

taken less than the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158 b_p \sqrt{\frac{|P|}{C_{CB} R_{eH}}}$$

where:

b_p : Breadth of plane corrugation plating:

$b_p = b_{f\text{-}cg}$ for flange plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

$b_p = b_{w\text{-}cg}$ for web plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

C_{CB} : Permissible bending stress coefficient for corrugated bulkhead plating taken equal to:

- For acceptance criteria set AC-S for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.
  $C_{CB} = 0.75$
- For acceptance criteria set AC-SD for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.
  $C_{CB} = 0.90$
- For horizontally corrugated longitudinal bulkheads, without being greater than $C_{CB\text{-}max}$.

$$C_{CB} = \beta_{CB} - \alpha_{CB} \frac{|\sigma_{hg}|}{R_{eH}}$$

β_{CB} : Coefficient as defined in Table 2.

α_{CB} : Coefficient as defined in Table 2.

$C_{CB\text{-}max}$: Maximum permissible bending stress coefficient as defined in Table 2.

Definition β_{CB}, α_{CB} and $C_{CB\text{-}max}$ **Table 2**

Acceptance criteria set	Structural member	β_{CB}	α_{CB}	$C_{CB\text{-}max}$
AC-S	Horizontally corrugated longitudinal bulkheads	0.90	0.50	0.75
AC-SD	Horizontally corrugated longitudinal bulkheads	1.05	0.50	0.90

1.2.2 Built-up corrugations

For built-up corrugations, with flange and web plate of different thickness, the net thickness, t_1 in mm, is to be taken as the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t_1 = \sqrt{\frac{0.0005 b_p^2 |P|}{C_{CB} R_{eH}} - t_2^2}$$

where:

t_1 : Net thickness of the thicker plating, either flange or web, in mm.

t_2 : Net thickness of the thinner plating, either flange or web, in mm.

b_P : Breadth of thicker plate, either flange or web, in mm.

C_{CB} : Permissible bending stress coefficient as defined in [1.2.1].

2 SPECIAL REQUIREMENTS

2.1 Minimum thickness of keel plating

2.1.1

The net thickness of the keel plating is not to be taken less than the offered net thickness of the adjacent 2m width bottom plating, measured from the edge of the keel strake.

The width of the keel is defined in Ch 3, Sec 6, [7.2.1].

2.2 Bilge plating

2.2.1 Definition of bilge plating

The definition of bilge plating is given in Ch 1, Sec 4, [3.8.1].

2.2.2 Bilge plating thickness

a) The net thickness of transversely stiffened bilge plating is not to be taken less than the net required thickness for the adjacent bottom shell plating and adjacent side shell plating, by Ch 6 and Ch 8, Sec 2 and Sec 3, whichever is greater. When bilge plating is divided into two or more strakes, in accordance with this requirement, the net thicknesses of lower and upper strakes are to be determined in comparison with the net required thicknesses of adjacent bottom shell plating and side shell plating respectively.

b) The net thickness of rounded bilge plating, t, in mm, is not to be taken less than:

$$t_{net} = 6.45\times10^{-4}(P_{ex}s_b)^{0.4}R^{0.6}$$

where:

P_{ex} : Design sea pressure for the design load set SEA-1 as defined in Ch 6, Sec 2, [2.1.3] calculated at the lower turn of the bilge, in kN/m^2.

R : Effective bilge radius in mm.

$$R = R_0 + 0.5(\Delta s_1 + \Delta s_2)$$

R_0 : Radius of curvature, in mm. See Figure 1.

Δs_1 : Distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Figure 1. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

Δs_2 : Distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Figure 1. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

s_b : Distance between transverse stiffeners, webs or bilge brackets, in mm.

c) Longitudinally stiffened bilge plating is to be assessed as regular stiffened plating. The bilge thickness is not to be less than the lesser of the value obtained by [1.1.1] and [2.2.2] b). A bilge keel is not considered as an effective 'longitudinal stiffening' member.

2.2.3 Transverse extension of bilge minimum plate thickness

Where a plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to be extended to the adjacent plate above the bilge provided the plate seam is not more than $s_2/4$ below the lowest side longitudinal. Similarly, for the flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be extended to the adjacent plate provided that the plate seam is not more than $s_1/4$ beyond the outboard bottom longitudinal. For definition of s_1 and s_2, see Figure 1.

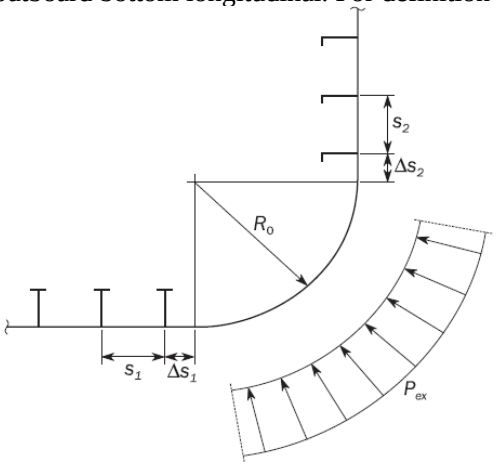


Figure 1 Transverse stiffened bilge plating

2.2.4 Hull envelope framing in bilge area

For transversely stiffened bilge plating, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The scantling of those longitudinals are to be not less than the one of the closer adjacent stiffener. The distance between the lower turn of bilge and the outermost bottom longitudinal, Δs_1, is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals, s_1. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, Δs_2, is generally not

to be greater than one-third of the spacing between the two lowest side longitudinals, s_2. See Figure 1.

2.3 Side shell plating

2.3.1 Fender contact zone

The net thickness, t in mm, of the side shell plating within the fender contact zone as specified in [2.3.2] is not to be taken less than:

$$t = 26\left(\frac{b}{1000} + 0.7\right)\left(\frac{BT_{SC}}{R_{eH}^{\ 2}}\right)^{0.25}$$

2.3.2 Application of fender contact zone requirement

The application extends within the cargo hold region as defined in Ch 1, Sec 1, [2.4.3], from the ballast draught T_{BAL} to $0.25T_{SC}$ (minimum 2.2 m) above T_{SC}.

2.4 Sheer strake

2.4.1 General

The minimum width of the sheer strake is defined in Ch 3, Sec 6, [8.2.4].

2.4.2 Welded sheer strake

The net thickness of a welded sheer strake is not to be less than the offered net thickness of the adjacent side plating, provided this adjacent side plating is located entirely within the top wing tank or double side tank as the case may be.

2.4.3 Rounded sheer strake

The net thickness of a rounded sheer strake is not to be less than:

- The offered net thickness of the adjacent 2 m width deck plating, or
- The offered net thickness of the adjacent 2 m width side plating, whichever is greater.

2.5 Deck stringer plating

2.5.1

The minimum width of deck stringer plating is defined in Ch 3, Sec 6, [9.1.2].

2.5.2

Within 0.6L of amidships, the net thickness of the deck stringer plate is not to be less than the offered net thickness of the adjacent deck plating.

2.6 Supporting structure in way of corrugated bulkheads

2.6.1 General

Requirements for the arrangement of bulkhead as given in Ch 3, Sec 6, [10.4] are to be considered together with [2.6.2] to [2.6.4].

2.6.2 Lower stool

a) The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the stool side plate, within the region of the corrugation depth from the stool top plate, is not to be less than the corrugated bulkhead flange net required thickness at the lower end and is to be of at least the same material yield strength. The net thickness may be reduced to 90% of corrugation flange thickness if continuity is provided between the corrugation web and supporting brackets inside the stool as defined in (c).

c) For oil tankers, continuity between corrugation web and lower stool supporting brackets is to be maintained inside the stool. Alternatively, lower stool supporting brackets inside the stool are to be aligned with every knuckle point of corrugation web.

d) The net thickness of supporting bracket is not to be less than 80% of the required net thickness of the corrugation webs and is to be of at least the same material yield strength.

e) The net thickness of supporting floors is not to be less than the net required thickness of the stool side plating (excluding the application of GRAB requirements as defined in Pt 2, Ch 1, Sec 6) connected to the inner bottom and is to be of at least the same material yield strength. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors *k*, as defined in Ch 3, Sec 1, [2.2.1].

f) Where a lower stool is fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see Ch 3, Sec 1, [2.5].

2.6.3 Upper stool

a) The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the lower portion of stool side plating is not to be less than the greater of the following,

- The net thickness obtained from [1.1],
- 80% of the net thickness of the upper part of the bulkhead plating as required by
  - [1.2],
  - Pt 2, Ch 1, Sec 3, [3.1], or Pt 2, Ch 2, Sec 3, [2.2.1] as applicable,

  where the same material is used.

If materials of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors k as defined in Ch 3, Sec 1, [2.2.1].

2.6.4 Local supporting structure in way of corrugated bulkheads without a lower stool

a) The net thickness of the supporting floors and pipe tunnel beams in way of a corrugated bulkhead are not to be less than the required net thickness of the corrugation flanges and are to be of at least the same material yield strength. The inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and Z grade steel as defined in Ch 3, Sec 1, [2.5.1] is to be used unless through thickness properties are documented for approval.

b) Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength. Where support is provided by gussets with shedder plates instead of brackets/carlings, the height of the gusset plate, see h_G in Pt 2, Ch 1, Sec 3, Figure 5, is to be at least equal to the corrugation depth. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates is not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flange and is to be of at least the same material yield strength.

2.7 Aft peak bulkhead

2.7.1

The net thickness of the aft peak bulkhead plating in way of the stern tube penetration is to be at least 1.6 times the required thickness for the bulkhead plating.

Section 5 STIFFENERS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

d_{shr} : Effective shear depth, in mm, as defined in Ch 3, Sec 7, [1.4.3].

l_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7, [1.1.2].

l_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7, [1.1.3].

P : Design pressure for the design load set being defined in Ch 6, Sec 2 and calculated at the load calculation point defined in Ch 3, Sec 7, [3.2], in kN/m^2.

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.90 for stiffeners attached to inner bottom or bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 STIFFENERS SUBJECT TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Web plating

The minimum net web thickness, *tw* in mm, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2], given by:

$$t_w = \frac{f_{shr}|P|sl_{shr}}{d_{shr}\chi C_t \tau_{eH}} \quad \text{with } C_t \text{ not to be taken greater than 1.0.}$$

where:

f_{shr} : Shear force distribution factor taken as:

- For continuous stiffeners with fixed ends, f_{shr} is not to be taken less than:
  - f_{shr} = 0.5 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{shr} = 0.7 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

- C_t = 0.75 for acceptance criteria set AC-S.
- C_t = 0.90 for *acceptance* criteria set AC-SD.

1.1.2 Section modulus

The minimum net section modulus, *Z* in cm3, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2.1.3], given by:

$$Z = \frac{|P|sl_{bdg}^2}{f_{bdg}\chi C_s R_{eH}} \quad \text{with } \chi\, C_s \text{ not to be taken greater than 1.0.}$$

where:

f_{bdg} : Bending moment factor taken as:

- For continuous stiffeners with fixed ends, f_{bdg} is not to be taken higher than:
  - f_{bdg} = 12 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{bdg} = 10 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_s : Permissible bending stress coefficient as defined in Table 1 for the design load set being considered.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [3.2].

β_s : Coefficient as defined in Table 2.

α_s : Coefficient as defined in Table 2.

$C_{s\text{-}max}$: Coefficient as defined in Table 2.

Definition of C_s **Table 1**

Sign of hull girder bending stress, σ_{hg}	Lateral pressure acting on	Coefficient C_s
Tension (positive)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression	Compression	
Tension (positive)	Plate side	
Compression (negative)	Stiffener side	$C_s = C_{s\text{-}max}$

Definition of β_s , α_s and $C_{s\text{-}max}$ **Table 2**

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC-S	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical member	0.75	0	0.75
AC-SD	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical member	0.9	0	0.9

1.1.3 Group of stiffeners

Scantlings of stiffeners based on requirements in [1.1.1] and [1.1.2] may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings on a single stiffened panel between primary supporting members. The scantling of the group is to be taken as the greater of the following:

- The average of the required scantling of all stiffeners within a group.
- 90% of the maximum scantling required for any one stiffener within the group.

1.1.4 Plate and stiffener of different materials

When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion is to be satisfied:

$$R_{eH-S} \le \left(R_{eH-P} - \frac{\alpha_S \lvert\sigma_{hg}\rvert}{\beta_S} \right) \frac{Z_P}{Z} + \frac{\alpha_S \lvert\sigma_{hg}\rvert}{\beta_S}$$

where:

$R_{eH\text{-}S}$: Minimum specified yield stress of the material of the stiffener, in N/mm^2.

$R_{eH\text{-}P}$: Minimum specified yield stress of the material of the attached plate, in N/mm^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1] with $\lvert\sigma_{hg}\rvert$ not to be taken less than 0.4 $R_{eH\text{-}P}$.

Z : Net section modulus, in way of face plate/free edge of the stiffener, in cm^3.

Z_P : Net section modulus, in way of the attached plate of stiffener, in cm^3.

α_s, β_s : Coefficients defined in Table 2.

1.2 Beam analysis

1.2.1 Direct analysis

The maximum normal bending stress, σ and shear stress, τ in a stiffener using net properties with reduced end fixity, variable load or being part of grillage are to be determined by direct calculations taking into account:

- The distribution of static and dynamic pressures and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the stiffener and at intermediate supports.
- The geometrical characteristics of the stiffener on the intermediate spans.

1.2.2 Stress criteria

The stress is to comply with the following criteria where the coefficients C_t and C_s, are defined in [1.1.1] and [1.1.2].

$$\tau \le \chi C_t \tau_{eH}$$

$$\sigma \le \chi C_s R_{eH}$$

Section 6 PRIMARY SUPPORTING MEMBERS AND PILLARS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Design pressure for the design load set being considered as defined in Ch 6, Sec 2 and calculated at the load calculation point as defined in Ch 3, Sec 7, [4.1.1], in kN/m^2.

l_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.6], in m.

l_{shr} : Effective shear span, as defined in Ch 3, Sec 7, [1.1.7], in m.

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.90 for primary supporting members attached to inner bottom or bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to primary supporting members subjected to lateral pressure and concentrated loads and pillars subjected to compressive axial loads. The yielding check is to be carried out for such members subjected to specific loads.

2 PRIMARY SUPPORTING MEMBERS WITHIN CARGO HOLD REGION

2.1 Flooded condition

2.1.1

The requirements in this sub-article apply to the primary supporting members of watertight boundaries other than outer shell or tank boundaries, subject to lateral pressure in flooded condition.

2.1.2

The verification against flooded condition is to be made by using the pressure and hull girder loads for the appropriate design load set as defined in Ch 6, Sec 2 and the scantling requirements given in [3.2].

2.2 Bulk carriers

2.2.1 Bulk carriers having a freeboard length L_{LL} of 150m and above

The scantlings of primary supporting members within the cargo hold region are to be verified by FE structural analysis as defined in Ch 7.

2.2.2 Bulk carriers having a freeboard length L_{LL} less than 150m

The scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 1, Sec 4, [4]. Alternatively, the scantlings of such members may be verified by direct strength assessment as deemed appropriate by the Society.

ISC 2.2.2a Alternatively, the scantlings of primary supporting members within the cargo area may be verified by direct strength assessment in accordance with the requirements of ISC 4.1.2a, Section 4, Chapter 1 of PART 9-2.

2.3 Oil tankers

2.3.1

Scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 2, Sec 3, [1] and are to be verified by FE structural analysis, as defined in Ch 7.

3 PRIMARY SUPPORTING MEMBERS OUTSIDE CARGO HOLD REGION

3.1 Application

3.1.1
The requirements of this article apply to primary supporting members, subjected to lateral pressure within the fore part, aft part and machinery space.

3.2 Scantling requirements

3.2.1 Net section modulus

The net section modulus, Z_{n50} in cm^3, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$Z_{n50} = 1000 \frac{|P| Sl_{bdg}{}^2}{\chi f_{bdg} C_s R_{eH}}$$

f_{bdg} : Bending moment distribution factor, as given in Table 2.
C_s : Permissible bending stress coefficient for the acceptance criteria set, as given in Table 1.

3.2.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$A_{shr-n50} = 10 \frac{f_{shr} |P| Sl_{shr}}{\chi C_t \tau_{eH}}$$

where:

f_{shr} : Shear force distribution factor, as given in Table
C_t : Permissible shear stress coefficient for the acceptance criteria set being considered, as given in Table 1.

Permissible bending and shear stress coefficients for primary supporting members Table 1

Acceptance criteria set	Structure attached to primary supporting member	C_s and C_t
AC-S	All boundaries, including decks and flats	0.70
AC-SD	All boundaries, including decks and flats	0.85

3.3 Advanced calculation methods

3.3.1 Direct analysis

Where complex grillage structures are employed or cross ties are fitted in side shell primary supporting members, the scantlings are to be determined by direct calculation taking into account:

- The distribution of still water and wave pressure and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the primary supporting members and at intermediate supports.
- The geometrical characteristics of the primary supporting members on the intermediate spans.

3.3.2 Analysis criteria

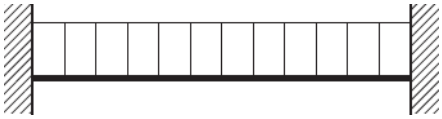
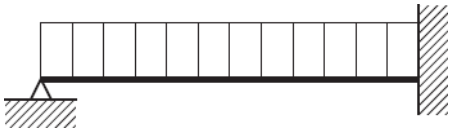
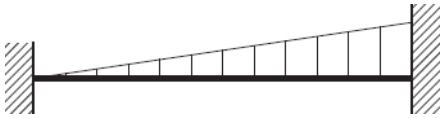
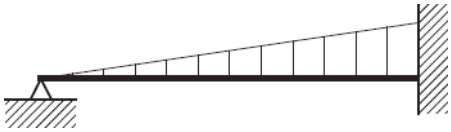
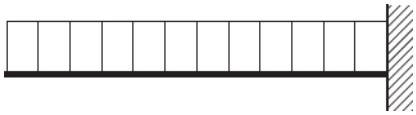
The calculated stresses are to comply with the following criteria where the coefficients C_t and C_s, are defined in [3.2]:

- $\sigma \leqslant \chi C_s R_{eH}$
- $\tau \leqslant \chi C_t \tau_{eH}$

where:

σ : Shear stress in member, in N/mm^2, based on t_{n50}.
τ : Normal stress in member, in N/mm^2, based on t_{n50}.

Bending moment and shear force factors, f_{bdg} and f_{shr} **Table 2**

Load and boundary condition				Bending moment and shear force distribution factors (based on load at mid span, where load varies)		
Position				1 f_{bdg1} f_{shr1}	2 f_{bdg2} -	3 f_{bdg3} f_{shr3}
Load model	1 Support	2 Field	3 Support			
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80
F				- -	- -	2.0 1.0

Note1: The bending moment distribution factor, f_{bdg} for the support positions is applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span of the primary supporting member.

Note2: The shear force distribution factor, f_{shr} for the support positions is applicable for a distance of 0.2 l_{shr} from the end of the effective shear span of the primary supporting member.

Note3: Application of f_{bdg} and f_{shr}:
The section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12.
The section modulus of mid-span area is to be determined using f_{bdg} = 24, or f_{bdg2} from the table if lesser.
The shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater.
For models A through F, the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid-span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

4 PILLARS

4.1 Pillars subjected to compressive axial load

4.1.1 Criteria

The maximum applied compressive axial load on a pillar, F_{pill}, in kN, is to be taken as the greatest value calculated for all applicable design load sets defined in Ch 6, Sec 2, [2], and is given by the following formula:

$F_{pill}=Pb_{a\text{-}sup}I_{a\text{-}sup}+F_{pill\text{-}upr}$

where:
$b_{a\text{-}sup}$: Mean breadth of area supported, in m.
$l_{a\text{-}sup}$: Mean length of area supported, in m.
$F_{pill\text{-}upr}$: Axial load from pillar including axial load from pillars above, in kN, if any.
$A_{pill\text{-}n50}$: Net cross section area of the pillar, in cm^2.
The buckling check of the pillar is to be performed according to Ch 8, Sec 4, [5.1], with σ_{av} in N/mm^2, as defined in Ch 8, Sec 5, [3.1] given by:

$$\sigma_{av} = 10\frac{F_{pill}}{A_{pill-n50}}$$

4.2 Pillars subject to tensile axial load

4.2.1 Criteria

Pillars and PSM members subjected to tensile axial load are to satisfy the criteria given in [3.3.2].

Chapter 7 DIRECT STRENGTH ANALYSIS

Section 1 STRENGTH ASSESSMENT

1 GENERAL

1.1 Application

1.1.1

This chapter provides requirements applicable to ships having rule a freeboard length L_{LL} of 150 m or above to assess the scantlings of the hull structure using finite element analysis.

1.1.2

The finite element analysis consists of three parts:

a) Cargo hold analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads.
b) Fine mesh analysis to assess detailed stress levels in local structural details.
c) Very fine mesh analysis to assess the fatigue capacity of the structural details according to Ch 9.

1.1.3

The strength assessment performed with finite element analysis is to verify that the scantlings comply with the acceptance criteria specified in this chapter for:

- Cargo hold structural analysis 6v-vvperformed in accordance with Ch 7, Sec 2.
- Local structural analysis performed in accordance with Ch 7, Sec 3.

1.1.4

Strength assessment based on finite element analysis is applicable for the entire cargo hold region.

1.1.5

The analysis is to verify the following:

a) Stress levels are within the acceptance criteria for yielding.
b) Buckling capability of plates and stiffened panels are within the acceptance criteria for bucking defined in Ch 8.
c) Fatigue capacity of structural details is within the acceptance criteria defined in Ch 9.

1.1.6

A flow diagram showing the minimum requirement of finite element analysis is shown in Figure 1.

2 NET SCANTLING

2.1 Net scantling application

2.1.1

FE models for cargo hold FE analyses, local fine mesh FE analysis and very fine mesh FE analyses, are to be based on the net scantling approach, applying a corrosion addition as defined in Ch 3, Sec 2, Table 1.

All buckling capacity assessment are to be based on corrosion addition, as defined in Ch 3, Sec 2, Table 1.

3 FINITE ELEMENT TYPES

3.1 Used finite element types

3.1.1

The structural assessment is to be based on linear finite element analysis of three dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Table 1.

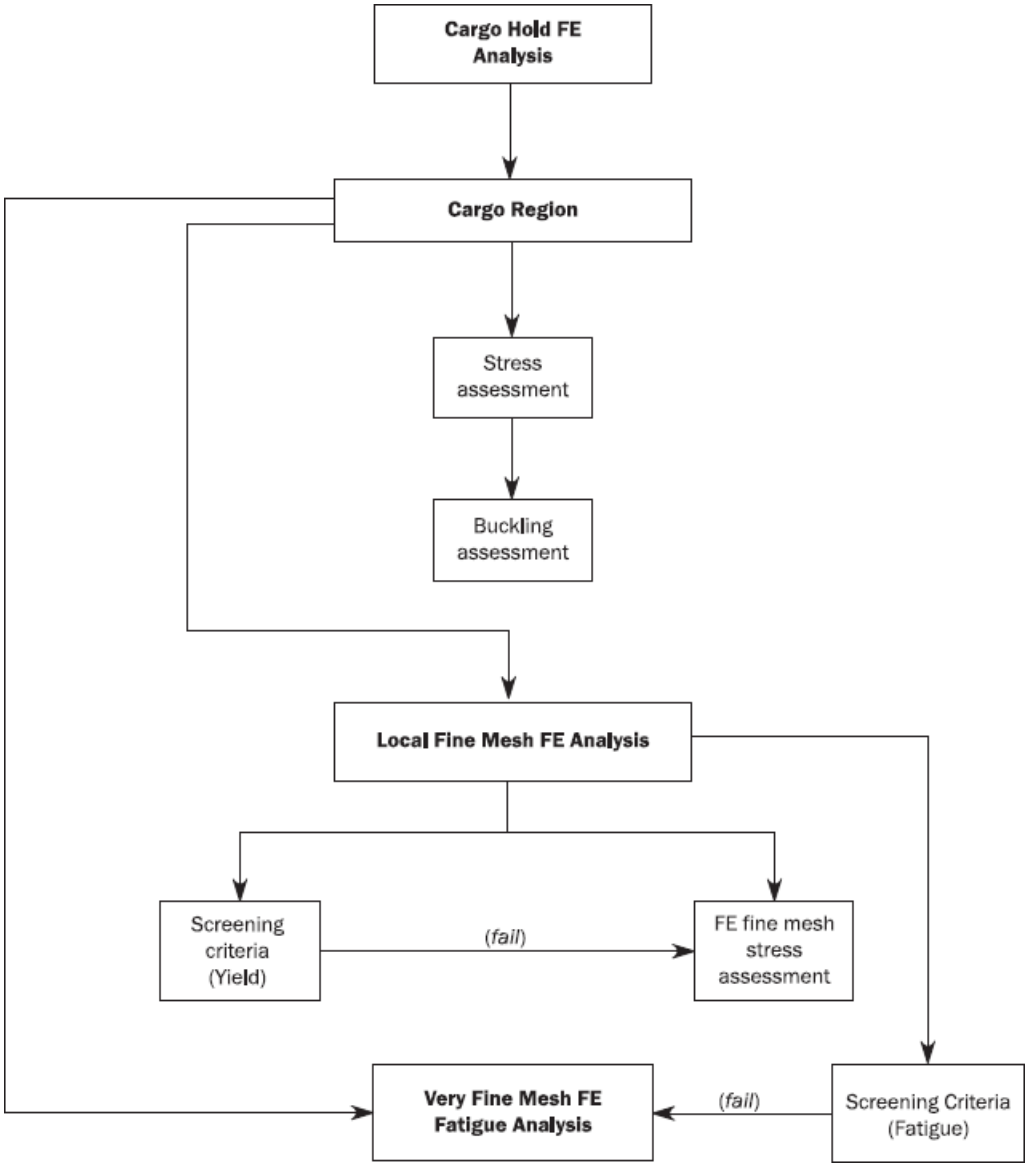


Figure 1 Flow diagram of finite element analysis

Types of finite element **Table 1**

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross sectional area along the length of the element.
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element.
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness.

3.1.2

Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure. The mesh requirements given in this chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

4 SUBMISSION OF RESULTS

4.1 Detailed report

4.1.1

A detailed report of the structural analysis is to be submitted by the designer/builder to demonstrate compliance with the specified structural design criteria. This report is to include the following information:

a) List of plans used including dates and versions.
b) Detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans.
c) Plots to demonstrate correct structural modelling and assigned properties.
d) Details of material properties, plate thickness, beam properties used in the model. e) Details of boundary conditions.
e) Details of all loading conditions reviewed with calculated hull girder shear force, bending moment and torsional moment distributions.
f) Details of applied loads and confirmation that individual and total applied loads are correct.
g) Plots and results that demonstrate the correct behaviour of the structural model under the applied loads.
h) Summaries and plots of global and local deflections.
i) Summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member.
j) Plate and stiffened panel buckling analysis and results.
k) Tabulated results showing compliance, or otherwise, with the design criteria.
l) Proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.
m) Reference of the finite element computer program, including its version and date.

5 COMPUTER PROGRAMS

5.1 Use of computer programs

5.1.1

Any finite element computation program complying with Ch 1, Sec 3 may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

Section 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible vertical still water bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wv} : Vertical wave bending moment, in kNm, in hogging or sagging condition, as defined in Ch 4, Sec 4.

M_{wh} : Horizontal wave bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wt} : Wave torsional moment in seagoing condition, in kNm, as defined in Ch 4, Sec 4.

Q_{sw} : Permissible still water shear force, in kN, at the considered bulkhead position, as provided in Ch 4, Sec 4.

Q_{wv} : Vertical wave shear force, in kN, as defined in Ch 4, Sec 4.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$: X-coordinate, in m, of respectively the aft and forward bulkhead of the mid-hold.

x_{aft} : X-coordinate, in m, of the aft end support of the FE model.

x_{fore} : X-coordinate, in m, of the fore end support of the FE model.

x_i : X-coordinate, in m, of web frame station i.

Q_{aft} : Vertical shear force, in kN, at aft bulkhead of mid-hold as defined in [4.4.6].

Q_{fwd} : Vertical shear force, in kN, at fore bulkhead of mid-hold as defined in [4.4.6].

$Q_{targ\text{-}aft}$: Target shear force, in kN, at the aft bulkhead of mid-hold as defined in [4.3.3].

$Q_{targ\text{-}fwd}$: Target shear force, in kN, at the forward bulkhead of mid-hold as defined in [4.3.3].

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The cargo hold structural strength analysis is used for the assessment of scantlings of longitudinal hull girder structural members, primary supporting members and bulkheads within the cargo hold region. This section gives the requirements for cargo hold structural strength analysis.

1.1.2

Cargo hold structural strength analysis is mandatory within the cargo hold region including the aft bulkhead of the aftmost cargo hold and the collision bulkhead. The evaluation areas are defined in [5.1].

1.1.3

For the purpose of FE structural assessment and load application, the cargo hold region contains the following cargo hold regions, which may vary depending on the ship length and cargo hold arrangement, as defined in Figure 1:

- Midship cargo hold region,
- Forward cargo hold region,
- After cargo hold region,
- Foremost cargo hold(s),
- Aftmost cargo hold(s).

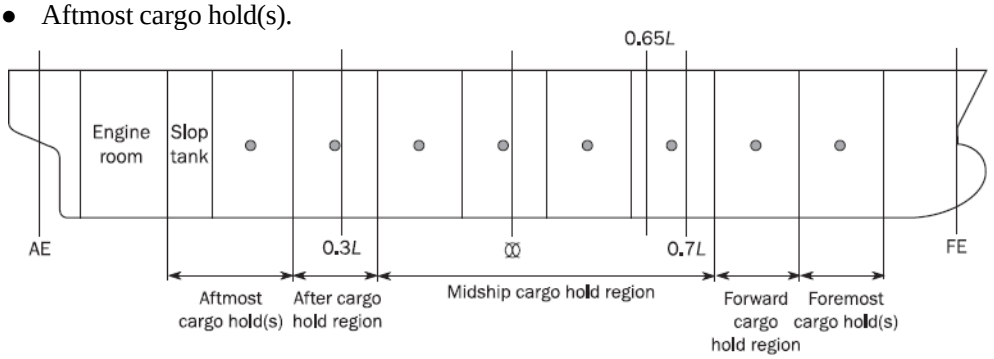


Figure 1 Definition of cargo hold regions for FE structural assessment

Holds in the forward cargo hold region are defined as holds with their longitudinal centre of gravity position forward of 0.7L from AE, except foremost cargo hold.

Holds in the midship cargo hold region are defined as holds with their longitudinal centre of

gravity position at or forward of 0.3*L* from AE and at or aft of 0.7*L* from AE.
Holds in the after cargo hold region are defined as holds with their longitudinal centre of gravity position aft of 0.3 *L* from AE, except aftmost cargo hold.
Foremost cargo hold(s) is (are) defined as hold(s) in the foremost location of the cargo hold region.
Aftmost cargo hold(s) is (are) defined as hold(s) in the aftmost location of the cargo hold region.

1.2 Cargo hold structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- Model: Three cargo hold model with:
  - Extent as given in [2.2]
  - Finite element types as given in [2.3]
  - Structural modelling as defined in [2.4]
- Boundary conditions as defined in [2.5]
- FE load combinations as defined in [3]
- Load application as defined in [4]
- Evaluation area as defined in [5.1]
- Strength assessment as defined in [5.2] and [5.3]

1.2.2 Mid-hold definition

For the purpose of the FE analysis, the mid-hold is defined as the middle hold(s) of the three cargo hold length FE model.
In case of foremost and aftmost cargo hold assessment, the mid-hold represents the foremost and aftmost cargo hold including the slop tank if any, respectively.

1.2.3 Scantling assessment

The scantling assessment is carried out according to Ch 7, Sec 1 for each individual cargo hold using the FE load combinations defined in Ch 4, Sec 8 applicable to the considered cargo hold. The FE analysis results are applicable to the evaluation area as defined in [5.1.1], of the considered cargo hold.
The individual transverse bulkhead structural elements, inclusive plating, stiffeners and horizontal stringers, are to be assessed considering two cargo hold finite element analyses, i.e. the analysis for the hold forward and the one for the hold aft of the considered transverse bulkhead.

2 STRUCTURAL MODEL

2.1 Members to be modelled

2.1.1

All main longitudinal and transverse structural elements are to be modelled. These include:

- Inner and outer shell,
- Deck,
- Double bottom floors and girders,
- Transverse and vertical web frames,
- Hatch coamings,
- Stringers,
- Transverse and longitudinal bulkhead structures,
- Other primary supporting members,
- Other structural members which contribute to hull girder strength.

All plates and stiffeners on the structure, including web stiffeners, are to be modelled. Brackets which contribute to primary supporting member strength and the size of which is not less than the typical mesh size (*s*-by-*s*) described in [2.4.2], are to be modelled.

2.2 Extent of model

2.2.1 Longitudinal extent

Except the foremost and aftermost cargo hold models, the longitudinal extent of the cargo hold FE model is to cover three cargo hold lengths. The transverse bulkheads at the ends of the model are to be modelled. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks/holds at the model ends. The

web frames at the ends of the model are to be modelled. Typical finite element models representing the midship cargo hold region of different ship type configurations are shown in Figure 3 and Figure 4.

The foremost and the aftmost cargo holds are located at the middle of the FE models as follows:

- Foremost cargo hold: from the after bulkhead of the cargo hold no. 2 to the ship's foremost cross section where the reinforced ring or web frame remains continuous from the base line to the strength deck.
- Aftermost cargo hold: from the after bulkhead of the engine room to the forward bulkhead of no. N-1 cargo hold, where N is the number of holds or sets of holds numbered from forward to aft.

Examples of finite element models representing the foremost and aftermost cargo holds of different ship type configurations are shown in Figure 5 and Figure 6.

2.2.2 Hull form modelling

In general, the finite element model is to represent the geometry of the hull form. In the midship cargo hold region, the finite element model may be prismatic provided the mid-hold has a prismatic shape.

In the foremost cargo hold model, the hull form forward of the transverse section at the middle of the fore part up to the model end as defined in [2.2.1] may be modelled with a simplified geometry. The transverse section at the middle of the fore part up to the model end may be extruded out to the fore model end, as shown in Figure 2.

In the aftmost cargo hold model, the hull form aft of the middle of the machinery space may be modelled with a simplified geometry. The section at the middle of the machinery space may be extruded out to its aft bulkhead, as shown in Figure 2.

When the hull form is modelled by extrusion, the geometrical properties of the transverse section located at the middle of the considered space (fore or machinery space) are copied along the simplified model. The transverse web frames are to be considered along this extruded part with the same properties as the ones in the fore part or in the machinery space.

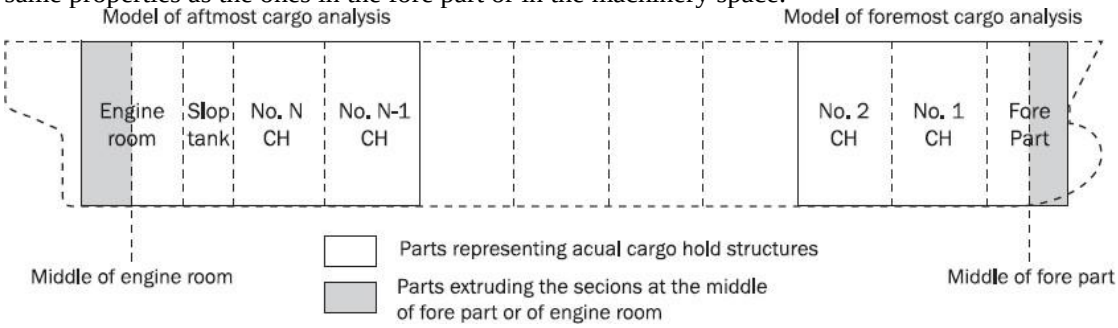


Figure 2 Hull form simplification for foremost and aftmost cargo hold model

2.2.3 Transverse extent

Both port and starboard sides of the ship are to be modelled.

2.2.4 Vertical extent

The full depth of the ship is to be modelled including primary supporting members above the upper deck, trunks, forecastle and/or cargo hatch coaming, if any.

The superstructure or deck house in way of the machinery space and the bulwark are not required to be included in the model.

2.3 Finite element types

2.3.1

Shell elements are to be used to represent plates.

2.3.2

All stiffeners are to be modelled with beam elements having axial, torsional, bi-directional shear and bending stiffness. The eccentricity of the neutral axis is to be modelled.

2.3.3

Face plates of primary supporting members and brackets are to be modelled using rod or beam elements.

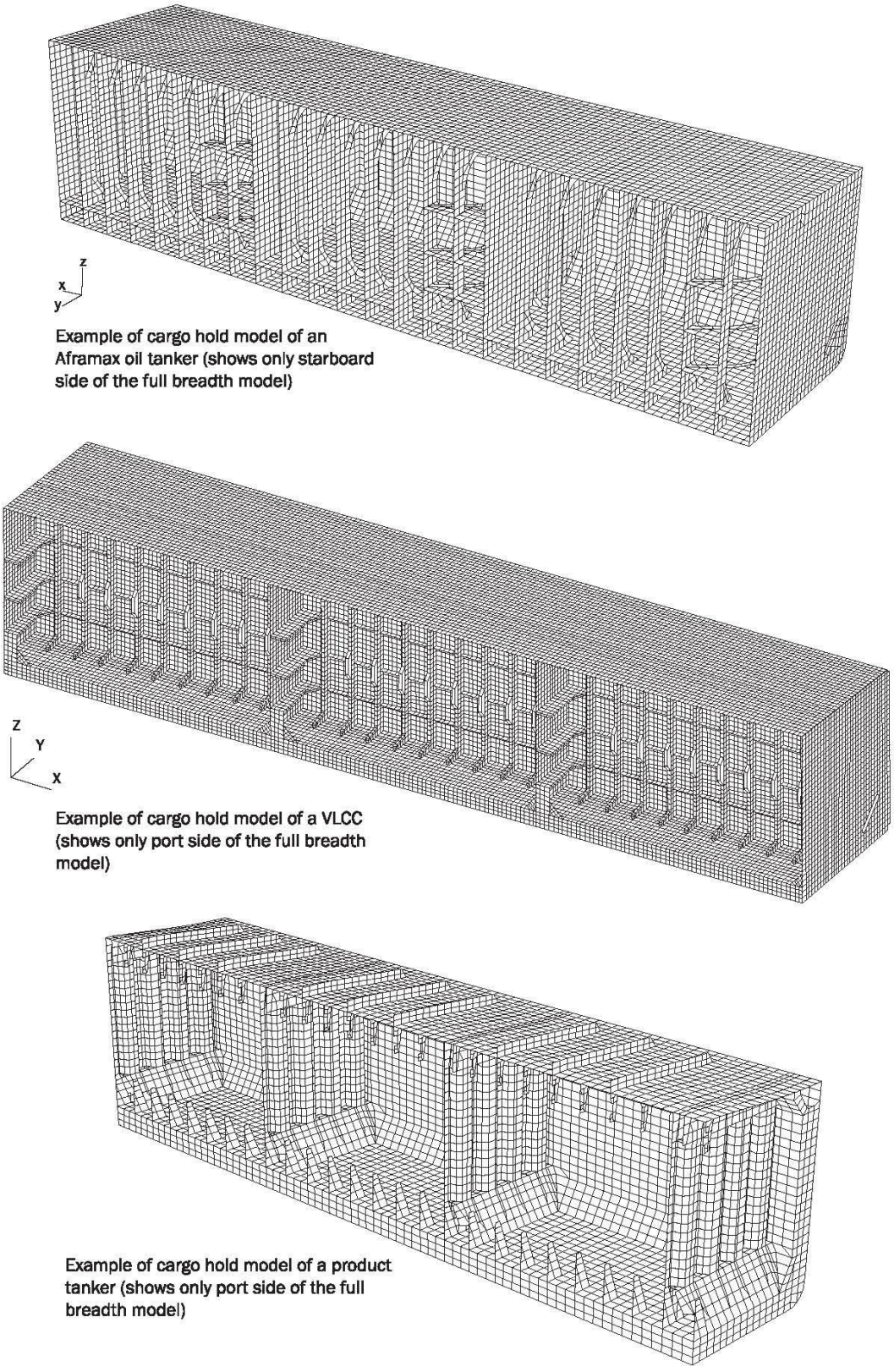


Figure 3 Example of 3 cargo hold model within midship region of oil tankers

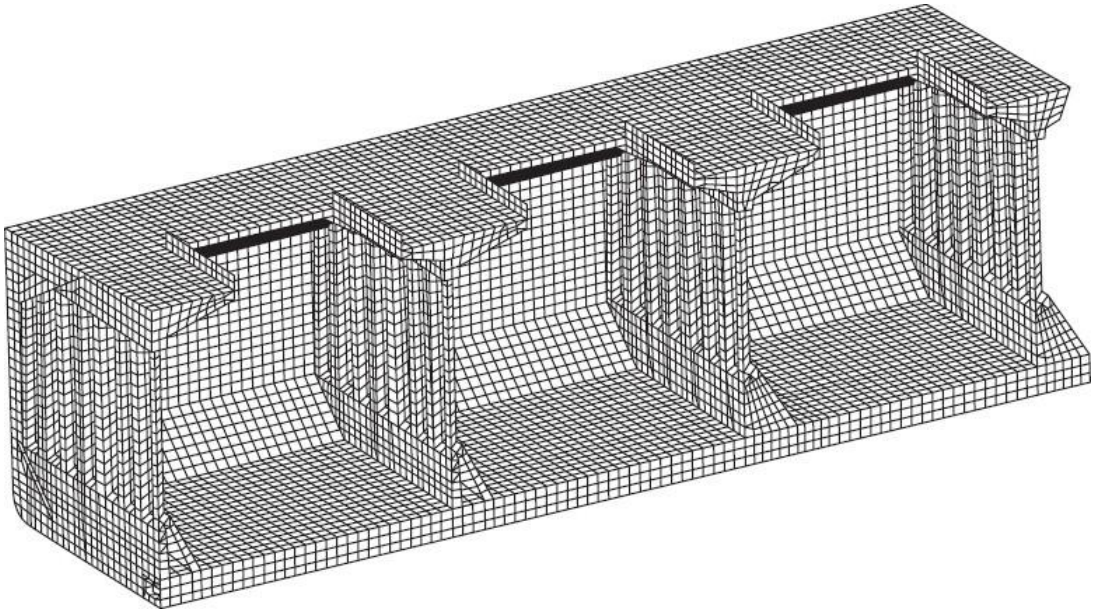


Figure 4 Example of 3 cargo hold model within midship region of a bulk carrier
Example of cargo hold model of a bulk carrier (shows only port side of the full breadth model)

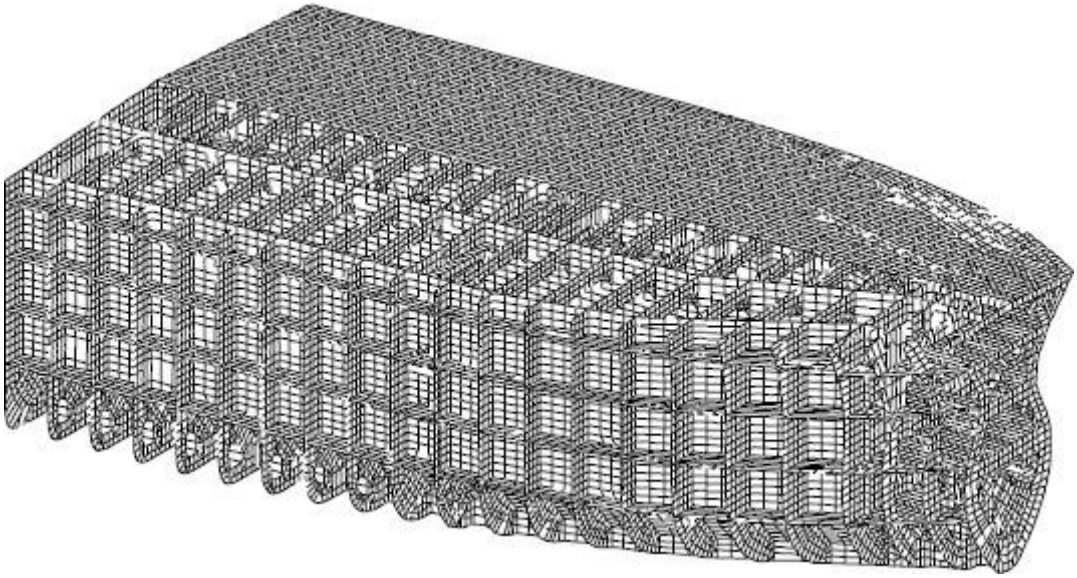


Figure 5 Example of FE model for the foremost cargo hold structure of an oil tanker

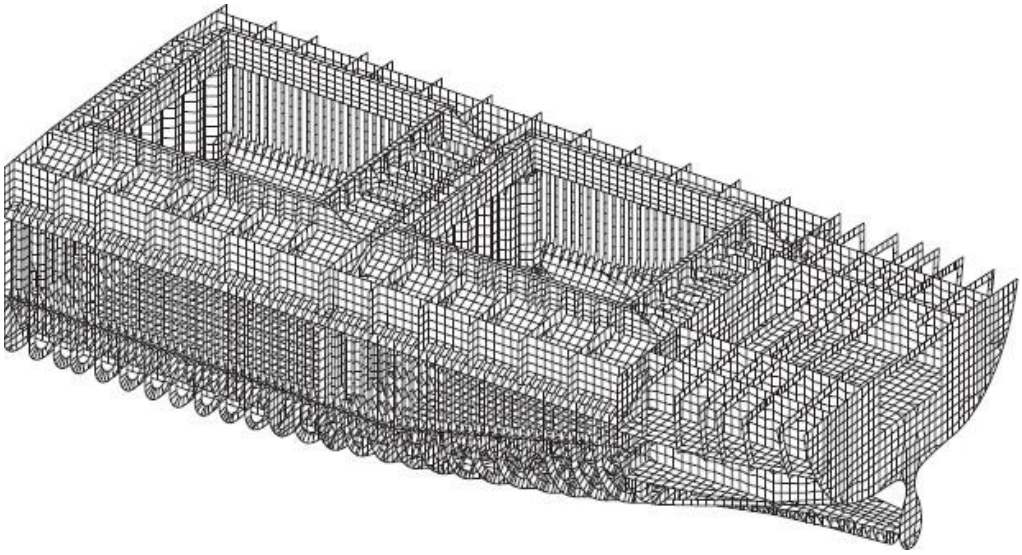


Figure 6 Example of FE model for the aftermost cargo hold structure of a bulk carrier

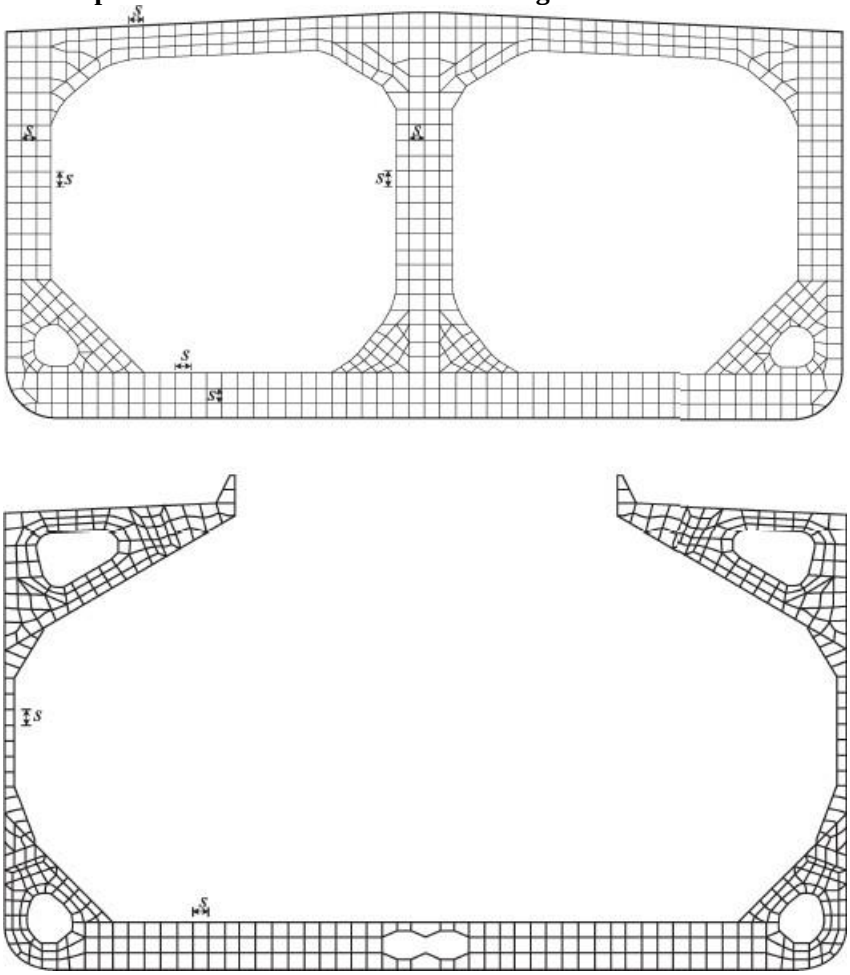


Figure 7 Typical finite element mesh on web frame

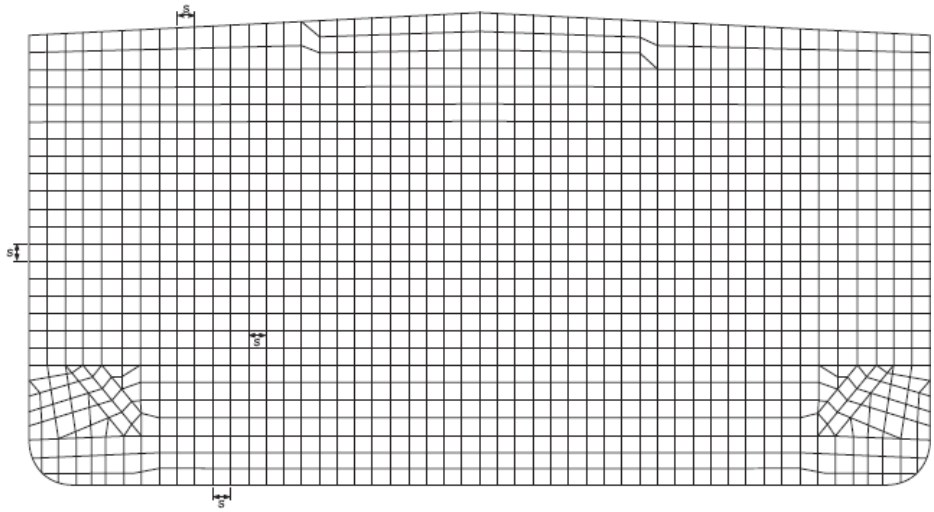


Figure 8 Typical finite element mesh on transverse bulkhead

s = Stiffener spacing

2.4 Structural modelling

2.4.1 Aspect ratio

The aspect ratio of the shell elements is in general not to exceed 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of shell elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to 1 and the use of triangular elements is to be avoided.

2.4.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

a) One element between every longitudinal stiffener, see Figure 7. Longitudinally, the element length is not to be greater than 2 longitudinal spaces with a minimum of three elements between primary supporting members.

b) One element between every stiffener on transverse bulkheads, see Figure 8.

c) One element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see Figure 7 and Figure 9.

d) At least 3 elements over the depth of double bottom girders, floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, modelling using 2 elements over the depth is acceptable provided that there is at least 1 element between every web stiffener. For a single side bulk carrier, 1 element over the depth of side frames is acceptable. The mesh size of adjacent structure is to be adjusted accordingly.

e) The mesh on the hopper tank web frame and the topside web frame is to be fine enough to represent the shape of the web ring opening, as shown in Figure 7.

f) The curvature of the free edge on large brackets of primary supporting members is to be modelled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, as shown in Figure 10. The modelling of the tapering part of the flange is to be in accordance with [2.4.8]. An example of acceptable mesh is shown in Figure 10. A finer mesh is to be used for the determination of detailed stress at the bracket toe, as given in Ch 7, Sec 3.

2.4.3 Finer mesh

Where the geometry cannot be adequately represented in the cargo hold model and the stress exceeds the cargo hold mesh acceptance criteria, a finer mesh may be used for such geometry to

demonstrate satisfactory scantlings. The mesh size required for such analysis can be governed by the geometry. In such cases, the average stress within an area equivalent to that specified in [2.4] is to comply with the requirements given in [5.2].

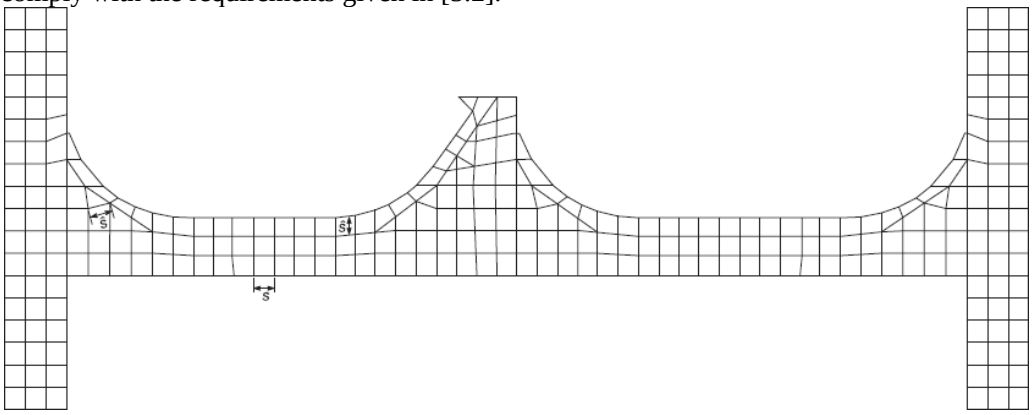


Figure 9 Typical finite element mesh on horizontal transverse stringer on transverse bulkhead

s = Stiffener spacing

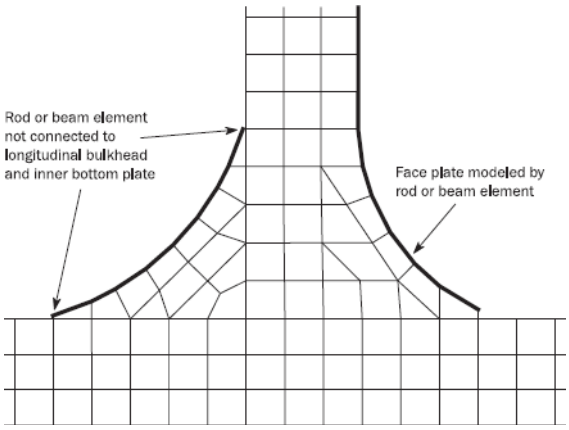


Figure 10 Typical finite element mesh on transverse web frame main bracket

2.4.4 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

a) The corrugation is to be modelled with its geometric shape.
b) The mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool.
c) The mesh on the longitudinal corrugated bulkhead is to follow longitudinal positions of transverse web frames, where the corrections to hull girder vertical shear forces are applied in accordance with [4.4.7].
d) The aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height.
e) Where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations.
f) For a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.
g) When corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm2 are to be modelled at the corrugation knuckle between the flange and the web. Dummy rod elements are to be used as minimum at the two corrugation knuckles closest to the intersection between:
   - Transverse and longitudinal bulkheads,
   - Transverse bulkhead and inner hull,

- Transverse bulkhead and side shell.

h) Manholes in diaphragms are to be modelled according to [2.4.9].

2.4.5

Example of mesh arrangements of the cargo hold structure are shown in Figure 11 to Figure 14.

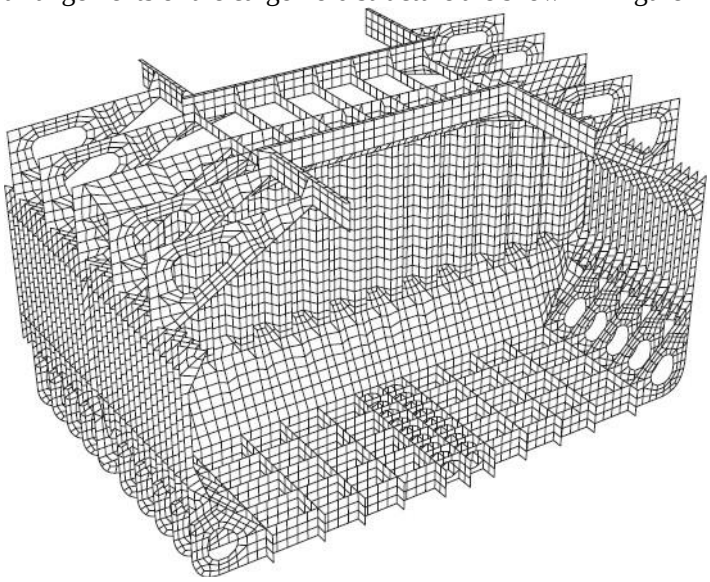


Figure 11 Example of FE mesh arrangements of cargo hold structure for a bulk carrier

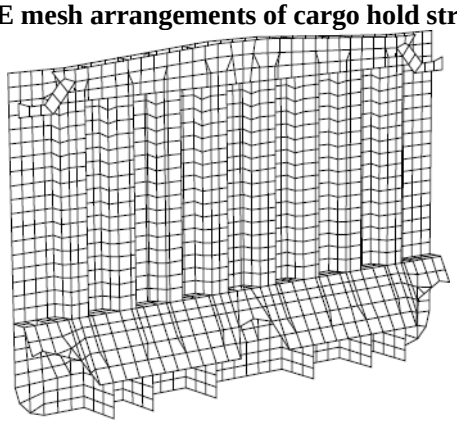


Figure 12 Example of FE mesh on transverse corrugated bulkhead structure for a product tanker

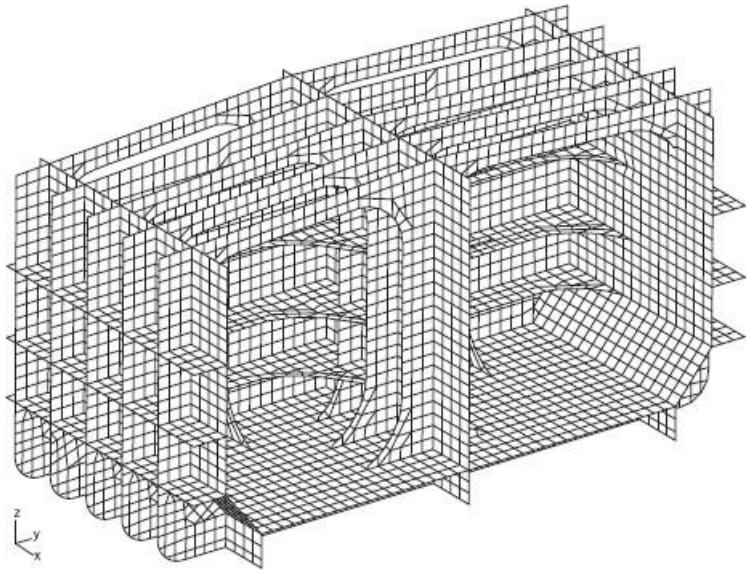


Figure 13 Example of FE mesh arrangements of cargo tank structure for an aframax tanker

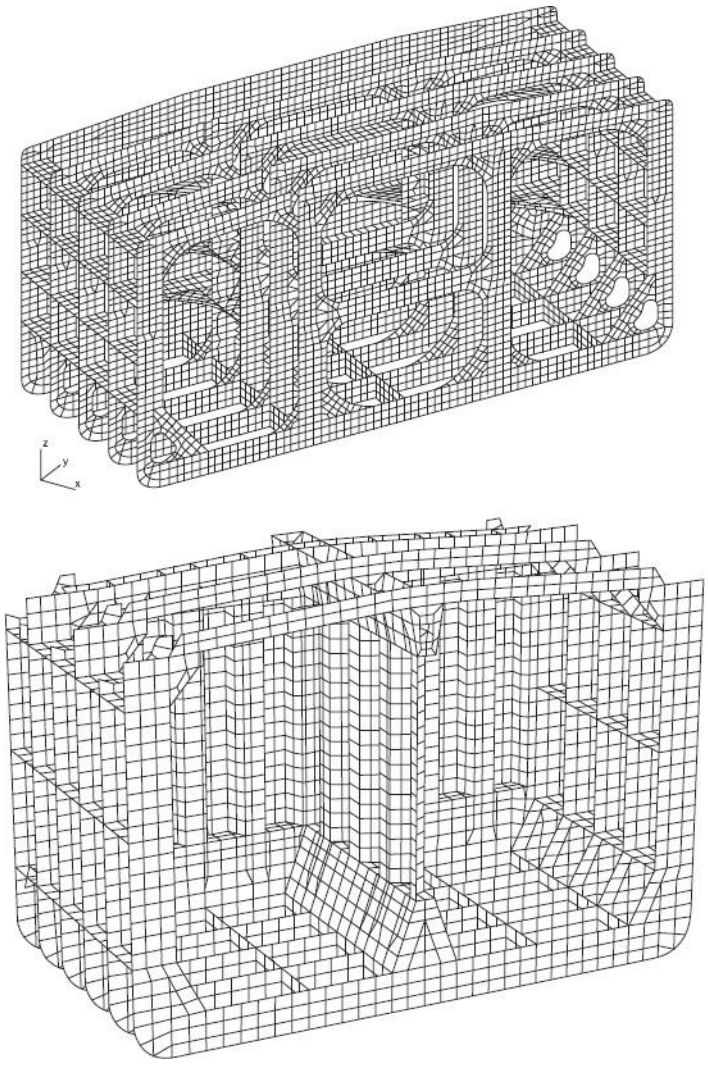


Figure 14 Examples of FE mesh arrangements of cargo tank structure for VLCC and product tanker

2.4.6 Sniped stiffener

Non continuous stiffeners are to be modelled as continuous stiffeners, i.e. the height web reduction in way of the snip ends are not to be modelled.

2.4.7 Web stiffeners of primary supporting members

Web stiffeners of primary supporting members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.4.8 Face plate of primary supporting member

The effective cross sectional area at the curved part of the face plate of primary supporting members and brackets is to be calculated in accordance with Ch 3, Sec 7. The cross sectional area of a rod or beam element representing the tapering part of the face plate is to be based on the average cross sectional area of the face plate in way of the element length.

2.4.9 Openings

Methods of representing openings and manholes in webs of primary supporting members are to be in accordance with Table1. Regardless of size, manholes are to be modelled by removing the appropriate elements.

Representation of openings in primary supporting member webs **Table 1**

Criteria	Modelling decision	Analysis
$h_o / h < 0.5$ and $g_o < 2.0$	Openings do not need to be modelled	To be evaluated by the screening procedure as given in Ch 7, Sec 3, 3.1.1
manholes	The geometry of the opening is to be modelled by removing the adequate elements	To be evaluated by the screening procedure as given in Ch 7, Sec 3, 3.1.1
$h_o / h \geqslant 0.5$ or $g_o \geqslant 2.0$	The geometry of the opening is to be modelled	To be evaluated by fine mesh as given in Ch 7, Sec 3, 2.1.1

where:

$$g_0 = \left(1 + \frac{l_0^2}{2.6(h - h_0)^2}\right)$$

l_0 : Length of opening parallel to primary supporting member web direction, in m, see Figure 15.
For sequential openings where the distance, d_o between openings is less than 0.25 h, the length l_0 is to be taken as the length across openings as shown in Figure 16.

h_o : Height of opening parallel to depth of web, in m, see Figure 15 and Figure 16.

h : Height of web of primary supporting member in way of opening, in m, see Figure 15 and Figure 16.

2.5 Boundary conditions

2.5.1 General

All boundary conditions described in this section are in accordance with the global coordinate system defined in Ch 4, Sec 1.

2.5.2 Application

The boundary conditions given [2.5.3] are applicable to cargo hold finite element model analyses in cargo hold region.

2.5.3 Boundary conditions

The boundary conditions consist of the rigid links at model ends, point constraints and end-beams. The rigid links connect the nodes on the longitudinal members at the model ends to an independent point at neutral axis in centreline. The boundary conditions to be applied at the ends of the cargo hold FE model, except for the foremost cargo hold, are given in Table 2. For the foremost cargo hold analysis, the boundary conditions to be applied at the ends of the cargo hold FE model are given in Table 3.

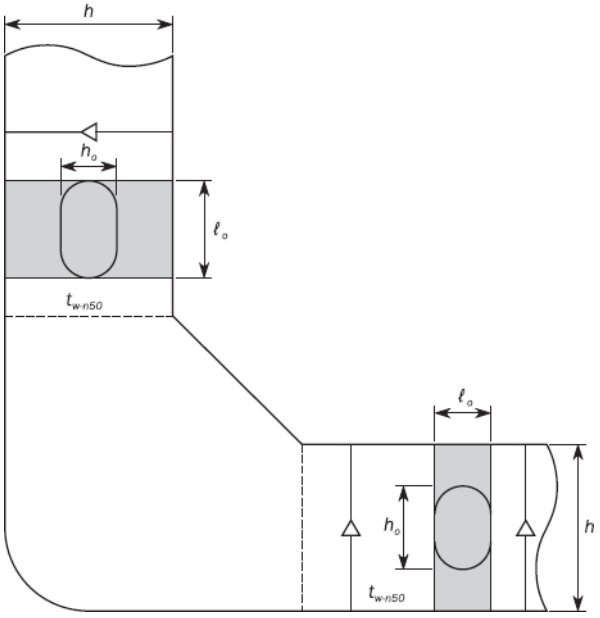


Figure 15 Openings in web

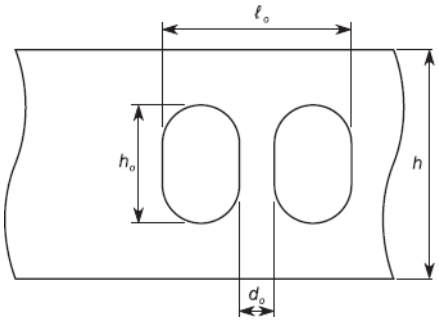


Figure 16 Length l_o for sequential openings with $d_o < h/4$

Boundary constraints at model ends except the foremost cargo hold models Table 2

Location	Translation			Rotation		
	θ_x	θ_y	θ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					

Note 1: [-] means no constraint applied (free).
Note 2: See Figure 17.

Boundary constraints at model ends of the foremost cargo hold model Table 3

Location	Translation			Rotation		
	θ_x	θ_y	θ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-

Note 1: [-] means no constraint applied (free).
Note 2: See Figure 17.
Note 3: Boundary constraints in fore end are to be located at the most forward reinforced ring or web frame which remains continuous from the base line to the strength deck.

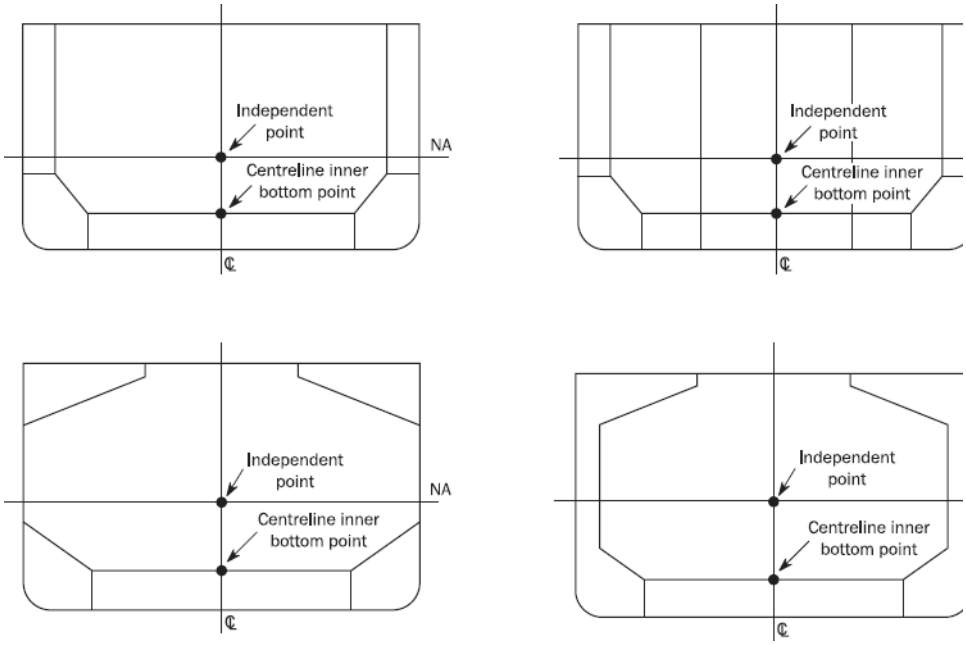


Figure 17 Boundary conditions applied at the model end sections

2.5.4 End constraint beams

End constraint beams are to be modelled at the both end sections of the model along all longitudinally continuous structural members and along the cross deck plating of bulk carriers. An example of end beams at one end for a double hull bulk carrier is shown in Figure 18.

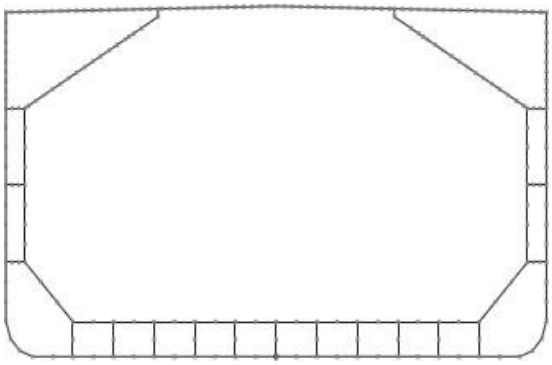


Figure 18 End constraint beams for a bulk carrier

The properties of beams are calculated at fore and after sections separately and all beams at each end section have identical properties as follows:

- Net moment of inertia: $I_{yy\text{-}n50} = I_{zz\text{-}n50} = I_{xx\text{-}n50}(J) = 1/25$ of the vertical hull girder moment of inertia of fore/aft end cross sections based on the net FE model.
- Net cross sectional area: $A_{y\text{-}n50}$ and $A_{z\text{-}n50} = 1/80$ of the fore/aft end cross sectional areas based on the net FE model.

where:

$I_{yy\text{-}n50}$: Moment of inertia about local beam *Y* axial, in m^4.
$I_{zz\text{-}n50}$: Moment of inertia about local beam *Z* axial, in m^4.
$I_{xx\text{-}n50}(J)$: Torsional inertia, in m^4.
$A_{y\text{-}n50}$: Shear area in local beam *Y* direction, in m^2.
$A_{z\text{-}n50}$: Shear area in local beam *Z* direction, in m^2.

3 FE LOAD COMBINATIONS

3.1 Design Load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading pattern, a draught, a value of still water bending and shear force, associated with a given dynamic load case.

3.1.2 Mandatory load combinations

For cargo hold structural strength analysis, the design load combinations specified in Ch4, Sec 8 are to be used for considered ship type and considered cargo hold regions.

Each design load combination given in Ch 4, Sec 8 consists of a loading pattern and dynamic load cases as given in Ch4, Sec 2. Each load combination requires the application of the structural weight, internal and external pressures and hull girder loads. For seagoing condition, both static and dynamic load components (S+D) are applied. For harbour and tank testing condition, only static load components (S) are applied.

3.1.3 Additional loading conditions

Where the loading conditions specified by the designer are not covered by the load combinations given in Ch4, Sec 8, these additional loading conditions are to be examined according to the procedure in [4].

4 LOAD APPLICATION

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in static loads, but is not to be included in dynamic loads. Density of steel is to be taken as given in Ch 4, Sec 6.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of moments and shear force is to be in accordance with the sign convention defined in Ch 4, Sec 1.

4.2 External and internal loads

4.2.1 External pressure

External pressure is to be calculated for each load case in accordance with Ch 4, Sec 5. External pressures include static sea pressure, wave pressure and green sea pressure.

The forces applied on the hatch cover by the green sea pressure are to be distributed along the top of the corresponding hatch coamings. The total force acting on the hatch cover is determined by integrating the hatch cover green sea pressure as defined in Ch 4, Sec 5, [5]. Then the total force is to be distributed to the total length of the hatch coamings using the average line load. The effect of the hatch cover self weight is to be ignored in the loads applied to the ship structure.

4.2.2 Internal pressure

Internal pressure is to be calculated for each load case in accordance with Ch 4, Sec 6 for design load scenarios given in Ch 4, Sec 7, Table 1. Internal pressures include static dry and liquid cargo, ballast and other liquid pressure, setting pressure on relief valve and dynamic pressure of dry and liquid cargo, ballast and other liquid pressure due to acceleration.

4.2.3 Pressure application on FE element

Constant pressure, calculated at the element's centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for external pressure and tank/hold boundaries for internal pressure. Alternately, pressure can be calculated at element nodes applying linear pressure distribution within elements.

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with its corresponding hull girder loads which is to be applied to the model according to the procedure described in [4.4] for shear force and bending moment and in [4.5] for torsional moment. The hull girder loads are the combinations of still water hull girder loads and wave induced hull girder loads as specified in Ch 4, Sec 8. For each required FE load combination, the wave induced hull girder loads are to be calculated with the Load Combination Factors (LCFs), specified in Ch 4, Sec 2.

4.3.2 Target hull girder vertical bending moment

The target hull girder vertical bending moment, $M_{v\text{-}targ}$, in kNm, at a longitudinal position for a

given FE load combination is taken as:

$M_{v\text{-}targ}=C_{BM\text{-}LC}M_{sw}+M_{wv\text{-}LC}$

where:

C_{BM-LC} : Percentage of permissible still water bending moment applied for the load combination under consideration as given in Ch 4, Sec 8,

M_{sw} : Permissible still water bending moments in kNm, at the considered longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.2.2] and Ch 4, Sec 4, [2.2.3] respectively.

M_{wv-LC}: Vertical wave bending moment in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.2].

The values of $M_{v\text{-}targ}$ are taken as:

Midship cargo hold region: the maximum hull girder bending moment within the mid-hold(s) for each individual cargo hold for each given FE load combination as defined in Ch 4, Sec 8.

Outside midship cargo hold region: the values at all web frame and transverse bulkhead positions of the FE model under consideration.

Both $C_{BM\text{-}LC}M_{sw}$ *and* $M_{wv\text{-}LC}$ are either in sagging or in hogging condition according to the FE load combinations given in the tables of Ch 4, Sec 8.

4.3.3 Target hull girder shear force

The target hull girder vertical shear force at the aft and forward transverse bulkheads of the mid-hold, $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$, in kN, for a given FE load combination is taken as:

- $Q_{fwd} \geqslant Q_{aft}$:

$$Q_{targ\text{-}aft} = C_{SF-LC} \cdot Q_{sw-neg} - \Delta Q_{swa} + f_{\beta} \left| C_{QW} \right| Q_{wv-neg}$$

$$Q_{targ\text{-}fwd} = C_{SF-LC} \cdot Q_{sw-pos} + \Delta Q_{swf} + f_{\beta} \left| C_{QW} \right| Q_{wv-pos}$$

- $Q_{fwd} < Q_{aft}$:

$$Q_{targ\text{-}aft} = C_{SF-LC} \cdot Q_{sw-pos} - \Delta Q_{swa} + f_{\beta} \left| C_{QW} \right| Q_{wv-pos}$$

$$Q_{targ\text{-}fwd} = C_{SF-LC} \cdot Q_{sw-neg} + \Delta Q_{swf} + f_{\beta} \left| C_{QW} \right| Q_{wv-neg}$$

where:

Q_{fwd}, Q_{aft} :Vertical shear forces, in kN, due to the local loads respectively at the forward and aft bulkhead position of the mid-hold, as defined in [4.4.6].

$C_{SF\text{-}LC}$: Percentage of permissible still water shear force as given in Ch 4, Sec 8, for the FE load combination under consideration.

$Q_{sw\text{-}pos}$, $Q_{sw\text{-}neg}$: Positive and negative permissible still water shear forces, in kN, at any longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.3.3] and Ch 4, Sec 4, [2.3.4] respectively.

ΔQ_{swf} : Shear force correction, in kN, for the considered FE loading pattern at the forward bulkhead taken as:

- For bulk carriers:

Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at forward bulkhead for the mid-hold and the value calculated at aft bulkhead of the forward cargo hold taken as:

$$\Delta Q_{swf} = \text{Min}(\left|\Delta Q_{mdf}\right|_{Mid}, \left|\Delta Q_{mdf}\right|_{Fwd})$$

- For oil tankers:

$\Delta Q_{swf} = 0$

ΔQ_{swa} : Shear force correction, in kN, for the considered FE loading pattern at the aft bulkhead taken as:

- For bulk carriers:

Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at aft bulkhead for the mid-hold and the value calculated at forward bulkhead of the aft cargo hold taken as:

$$\Delta Q_{swa} = \text{Min}(\left|\Delta Q_{mdf}\right|_{Mid}, \left|\Delta Q_{mdf}\right|_{Aft})$$

- For oil tankers:

$\Delta Q_{swa}=0$

f_β : Wave heading factor, as given in Ch 4, Sec 4.
C_{QW} : Load combination factor for vertical wave shear force, as given in Ch 4, Sec 2.
$Q_{wv\text{-}pos}$, Q_{wv_neg} : Positive and negative vertical wave shear force, in kN, as defined in Ch 4, Sec 4, [3.2.1].
The values of $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$ are to be taken at after and forward transverse bulkheads of the mid-hold under consideration.

4.3.4 Target hull girder horizontal bending moment

The target hull girder horizontal bending moment, $M_{h\text{-}targ}$, in kNm, for a given FE load combination is taken as:

$$M_{h-targ} = M_{wh-LC}$$

where:

M_{wh-LC}: Horizontal wave bending moment, in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.4].

The values of $M_{wh\text{-}LC}$ are taken as:

- Midship cargo hold region: the value calculated for the middle of the individual cargo hold under consideration.
- Outside midship cargo hold region: the values calculated at all web frame and transverse bulkhead positions of the FE model under consideration.

4.3.5 Target hull girder torsional moment

For bulk carriers only, the target hull girder torsional moment, $M_{wt\text{-}targ}$, in kNm, for the dynamic load cases OST and OSA is the value at the target location taken as:

$$M_{wt-targ} = M_{wt-LC}\,(x_{targ})$$

where:

$M_{wt\text{-}LC\,(x)}$: Wave torsional moment, in kNm, for the dynamic load case OST and OSA, defined in Ch 4, Sec 4, [3.5.5], calculated at x position.

x_{targ} : Target location for hull girder torsional moment taken as:

- For midship cargo hold region:
  - If $x_{mid} \leqslant 0.531\,L$: after bulkhead of the mid-hold.
  - If $x_{mid} > 0.531\,L$: forward bulkhead of the mid-hold.
- Outside midship cargo hold region:
  The transverse bulkhead of mid-hold where the following formula is minimum:

$$\frac{M_{wt-LC}(x_{bhd})}{\left|M_{wt-LC}(x_{bhd})\right|}\cdot\left[M_{wt-LC}(x_{bhd}) - M_{T-FEM}(x_{bhd})\right]$$

x_{mid} : X-coordinate, in m, of the mid-hold centre.

x_{bhd} : X-coordinate, in m, of the after or forward transverse bulkhead of mid-hold.

For dynamic load cases of bulk carriers other than OST and OSA and for all dynamic load cases of oil tankers, hull girder torsional moment $M_{wt\text{-}targ}$, at middle of mid-hold is to be adjusted to zero.

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.1 General

The procedure given in this sub-article [4.4] describes how to adjust the hull girder horizontal bending moment, vertical force and vertical bending moment distribution on the three cargo hold FE model to achieve the required target values at required locations. The hull girder load target values are specified in [4.3].

The target locations for hull girder shear force are at the transverse bulkheads of the mid-hold. The final adjusted hull girder shear force at the target location should not exceed the target hull girder shear force.

The target location for hull girder bending moment is, in general, located at the centre of the mid-hold. If the maximum value of bending moment is not located at the centre of the mid-hold, the final adjusted maximum bending moment within the mid-hold is not to exceed the target hull girder bending moment.

4.4.2 Local load distribution

The following local loads are to be applied for the calculation of hull girder shear and bending

moments:

a) Ship structural steel weight distribution over the length of the cargo hold model (static loads). The structural steel weight is to be calculated based on the FE model with a net thickness of 0.5 *tc* deduction, as used in the cargo hold FE model.
b) Weight of cargo and ballast (static loads).
c) Static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the harbour/tank testing load cases, only static sea pressure needs to be applied.
d) Dynamic cargo and ballast loads for seagoing load cases.

With the above local loads applied to the FE model, the FE nodal forces are obtained through FE loading procedure. The 3D nodal forces will then be lumped to each longitudinal station to generate the one dimension local load distribution. The longitudinal stations are located at transverse bulkheads/frames and typical longitudinal FE model nodal locations in between the frames according to the cargo hold model mesh size requirement. Any intermediate nodes created for modelling structural details are not treated as the longitudinal stations for the purpose of local load distribution. The nodal forces within half of forward and half of afterward of longitudinal station spacing are lumped to that station. The lumping process will be done for vertical and horizontal nodal forces separately to obtain the lumped vertical and horizontal local loads, f_{vi} and f_{hi}, at the longitudinal station *i*.

4.4.3 Hull girder forces and bending moment due to local loads

With the local load distribution, the hull girder load longitudinal distributions are obtained by assuming the model is simply supported at model ends. The reaction forces at both ends of the model and longitudinal distributions of hull girder shear forces and bending moments induced by local loads at any longitudinal station are determined by the following formulae:

$$R_{V_fore} = -\frac{\sum_j (x_i - x_{aft}) f_{vi}}{x_{fore} - x_{aft}} \qquad R_{V_aft} = \sum_i f_{vi} + R_{V_fore}$$

$$R_{H_fore} = -\frac{\sum_j (x_i - x_{aft}) f_{hi}}{x_{fore} - x_{aft}} \qquad R_{V_aft} = \sum_i f_{vi} + R_{H_fore}$$

$$F_l = \sum_i f_{li}$$

$$Q_{V_FEM}(x_j) = R_{V_aft} - \sum_i f_{hi} \qquad \text{when} x_i < x_j$$

$$Q_{H_FEM}(x_j) = R_{H_aft} + \sum_i f_{hi} \qquad \text{when} x_i < x_j$$

$$M_{V_FEM}(x_j) = R_{V_aft} - \sum_i (x_j - x_i) f_{vi} \quad \text{when} \quad x_i < x_j$$

$$M_{H_FEM}(x_j) = R_{H_aft} + \sum_i (x_j - x_i) f_{hi} \quad \text{when} \quad x_i < x_j$$

Where:

R_{V_aft}, R_{V_fore}, R_{H_aft}, R_{H_fore} : Vertical and horizontal reaction forces at the aft and fore ends, in kN.

x_{aft} : *X*-coordinate of the aft end support, in m.

x_{fore} : *X*-coordinate of the fore end support, in m.

f_{vi} :Lumped vertical local load at longitudinal station *i* as defined in [4.4.2], in kN.

f_{hi} :Lumped horizontal local load at longitudinal station *i* as defined in [4.4.2], in kN.

F_l : Total net longitudinal force of the model, in kN.

f_{li} : Lumped longitudinal local load at longitudinal station *i* as defined in [4.4.2], in kN.

x_j : *X*-coordinate, in m, of considered longitudinal station *j*.

x_i : *X*-coordinate, in m, of longitudinal station *i*.

$Q_{V_FEM}(x_j)$, $Q_{H_FEM}(x_j)$, $M_{V_FEM}(x_j)$, $M_{H_FEM}(x_j)$: Vertical and horizontal shear forces, in kN, and bending moments, in kNm, at longitudinal station x_j created by the local loads applied on the FE model. The sign convention for reaction forces is that a positive creates a positive shear force.

4.4.4 Longitudinal unbalanced force

In case total net longitudinal force of the model, F_l, is not equal to zero, the counter longitudinal force, $(F_x)_j$, is to be applied at one end of the model, where the translation on X-direction, δ_x, is fixed, by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements, as follows:

$$(F_x)_j = \frac{F_l}{A_{x-n50}} \frac{A_{j-n50}}{n_j}$$

where:

$(F_x)_j$: Axial force applied to a node of the j-th element, in kN.

F_l : Total net longitudinal force of the model, as defined in [4.4.3], in kN.

$A_{j\text{-}n50}$: Net cross sectional area of the j-th element, in m^2.

$A_{x\text{-}n50}$: Net cross sectional area of fore end section, in m^2,

$$A_{x-n50} = \sum_j A_{j-n50}$$

n_j : Number of nodal points of j-th element on the cross section, $n_j = 1$ for beam element, $n_j = 2$ for 4- node shell element.

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all FE load combinations given in Ch 4, Sec 8. The FE load combinations not directly covered by the load combination tables of Ch 4, Sec 8 are to be considered on a case by case basis.

The two following methods are to be used for the shear force adjustment:

- Method 1 (M1): for shear force adjustment at one bulkhead of the mid-hold as given in [4.4.6],
- Method 2 (M2): for shear force adjustment at both bulkheads of the mid-hold as given in [4.4.7].

For the considered FE load combination, the method to be applied is to be selected as follows:

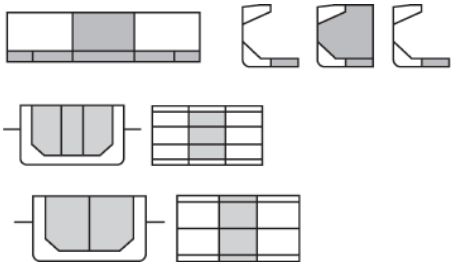
- For maximum shear force load combination (Max SFLC), the method 1 applies at the bulkhead mentioned in Table 4 if the shear force after the adjustment with method 1 at the other bulkhead does not exceed the target value. Otherwise, the method 2 applies.
- For other shear force load combination:
  - The shear force adjustment is not requested when the shear forces at both bulkheads are lower or equal to the target values. This applies to cargo hold analysis in whole cargo area except for aft most and foremost cargo hold.
    For aft most and foremost cargo hold analyses, the shear force adjustment is to be applied with method 1. The target hull girder vertical shear force at the aft and forward transverse bulkheads, $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$, are to be set to values of vertical shear force due to local loads Q_{aft} and Q_{fwd} accordingly:
    $$Q_{targ-fwd} = Q_{fwd}$$
    $$Q_{targ-aft} = Q_{aft}$$
  - The method 1 applies when the shear force exceeds the target at one bulkhead and the shear force at the other bulkhead after the adjustment with method 1 does not exceed the target value. Otherwise the method 2 applies,
  - The method 2 applies when the shear forces at both bulkheads exceed the target values,

ISC 4.4.5a For the considered conditions not included in the tables of loading conditions in Section 8, Chapter 4, the hull girder shear force is to be adjusted as follows:

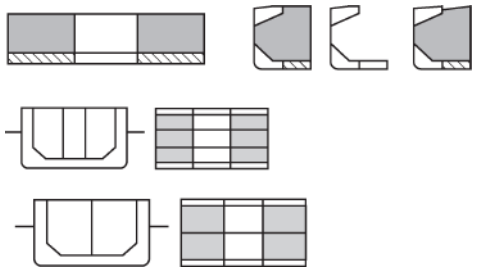
(1) The shear force of hull girders is to be adjusted for the following load combinations:

① Loading pattern: alternate loading of holds in longitudinal direction.

(a) All middle holds are loaded while end holds are empty, as shown in the figure below.



(b) All middle holds are empty while end holds are loaded, as shown in the figure below.

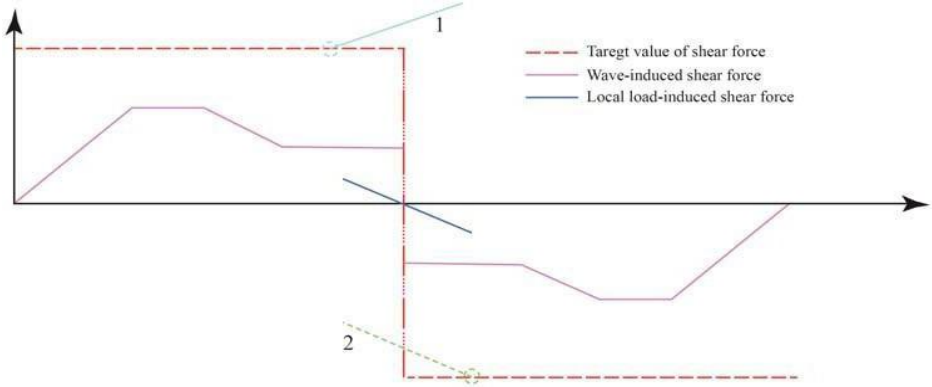


② Dynamic load cases: head sea model (HSM) or following sea model (FSM) or harbor condition.

③ Target bulkheads:

(a) For the model of a mid-hold of which both fore and aft bulkheads are located fore or aft of 0.5L amidships, the shear force adjustment is to be made at the bulkhead location defined in Table 4, Section 2, Chapter 7.

(b) For the model of a mid-hold situated amidships, of which the fore bulkhead is located fore of 0.5L amidships and the aft bulkhead aft of 0.5L amidships, the shear force adjustment is to be made at the bulkhead location where the absolute target value is greater. E.g.: where the absolute target value at the aft bulkhead is greater than that at the fore bulkhead, the shear force adjustment is to be made at the aft bulkhead location according to 1 as shown in the figure below, otherwise according to 2.



④ Method of hull girder shear force adjustment:

The method of hull girder shear force adjustment is to be in accordance with 4.4.5 Section 2 Chapter 7.

(2) For other load combinations:

The hull girder shear force adjustment is to be in accordance with 4 .4.5 Section 2 Chapter 7.

(3) The tart hull girder shear force are to be taken in accordance with 4.3 Section 2 Chapter 7 and the shear force adjustment procedure is to be in accordance with the relevant requirements of 4.4 Section 2 Chapter 7.

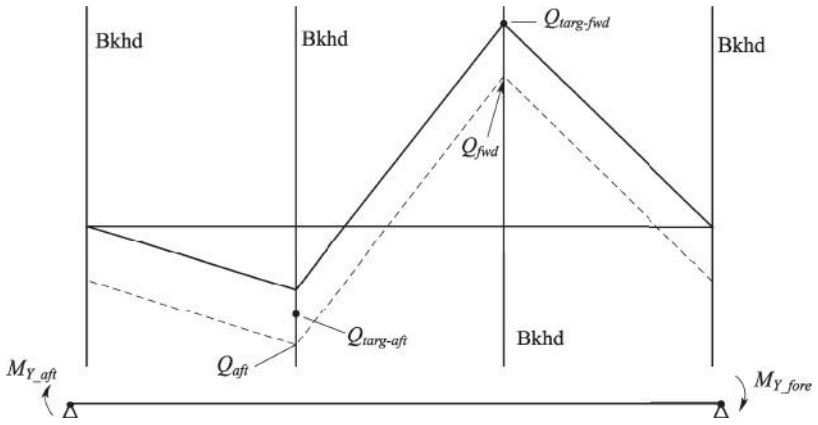
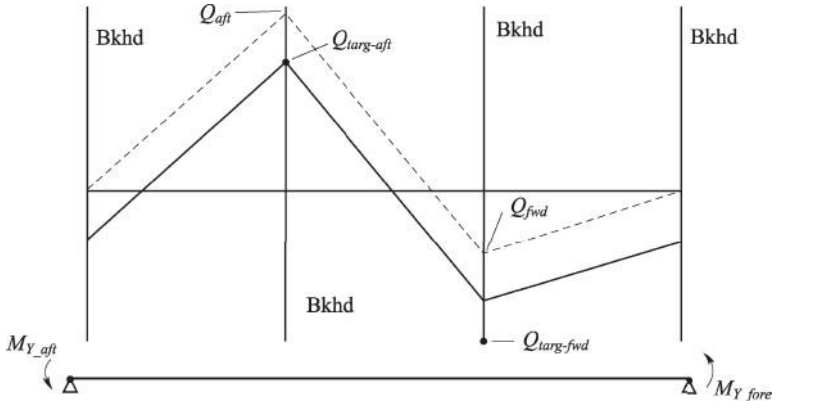
Mid-hold bulkhead location for shear force adjustment **Table 4**

Design loading conditions	Bulkhead location	$M_{wv\text{-}LC}$	Condition on Q_{fwd}	Mid-hold bulkhead for SF adjustment
Seagoing conditions	$X_{b\text{-}aft} > 0.5L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leqslant Q_{aft}$	Aft
		0 (hogging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leqslant Q_{aft}$	Fwd
	$X_{b\text{-}fwd} < 0.5L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leqslant Q_{aft}$	Fwd

Design loading conditions	Bulkhead location	$M_{wv\text{-}LC}$	Condition on Q_{fwd}	Mid-hold bulkhead for SF adjustment
		0 (hogging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leqslant Q_{aft}$	Aft
	$X_{b\text{-}aft} \leqslant 0.5L$ and $X_{b\text{-}fwd} \geqslant 0.5L$	-	-	(1)
Harbour and testing conditions	whatever the location	-	-	(1)

(1) For the FE load combinations covered by the load combination tables of Ch 4, Sec 8, the bulkhead where the shear force adjustment is to be done is indicated in those tables.

Vertical shear force adjustment by application of vertical bending moments M_{Y_aft} and M_{Y_fore} for method 1 **Table 5**

Vertical shear force diagram	Target position in mid-hold
	Forward bulkhead
	Aft bulkhead
Vertical shear force after adjustment Vertical shear due to local adjustment	

4.4.6 Method 1 for vertical shear force adjustment at one bulkhead

The required adjustments in shear force at aft or forward transverse bulkhead of the mid-hold are to be made by applying vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends. For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Table 7:

- $\delta w'_1$ - for aft most cargo hold model
- $\delta w'_3$ - for foremost cargo hold model

The required adjustments in shear force at following transverse bulkheads of the mid-hold are given by:

- Aft bulkhead:

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-aft} - Q_{aft}) - M'_{1-aft}$$

$$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

$$\delta w'_1 = \frac{Q_{targ-aft} - Q_{aft} + R_{v_aft}}{(n_1 - 1)} \quad \text{for aftmost cargo hold model only}$$

$$\delta w'_3 = \frac{Q_{targ-aft} - Q_{aft} + R_{v_fore}}{(n_3 - 1)} \quad \text{for foremost cargo hold model only}$$

- Forward bulkhead:

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-fwd} - Q_{fwd}) - M'_{1-fwd}$$

$$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

$$\delta w'_1 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v_aft}}{(n_1 - 1)} \quad \text{for aftmost cargo hold model only}$$

$$\delta w'_3 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v_fore}}{(n_3 - 1)} \quad \text{for foremost cargo hold model only}$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment as shown in Table 5. The sign convention is that of the FE model axis.

Q_{aft} : Vertical shear force, in kN, due to local loads at aft bulkhead location of mid-hold, x_{b_aft}, resulting from the local loads calculated according to [4.4.3].Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{aft} is the maximum absolute shear force between the stations located right after and right forward of the aft bulkhead of mid-hold.

Q_{fwd} : Vertical shear force, in kN, due to local loads at the forward bulkhead location of mid-hold, $x_{b\text{-}_fwd}$, resulting from the local loads calculated according to [4.4.3].Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward of the forward bulkhead of mid-hold.

$M'_{1\text{-}aft}$,$M'_{1\text{-}fwd}$: Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- Aft most cargo hold model

$$M'_{1-aft} = \frac{l_1}{4}(Q_{targ-aft} - Q_{aft} + R_{v-aft})$$

$$M'_{1-fwd} = \frac{l_1}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-aft})$$

- Foremost cargo hold model

$$M'_{1-aft} = \frac{l_3}{4}(Q_{targ-aft} - Q_{aft} + R_{v-fore})$$

$$M'_{1-fwd} = \frac{l_3}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-fore})$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Table 8.

ΔQ_{aft} ,ΔQ_{fwd} : Shear force adjustments, as given in Table 8

R_{v_aft}, M_{v_fore} : Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].

l_1 : Length of the modelled engine room in aftmost cargo hold model, in m. See also

Table 8.

l_3 : Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.

n_1, n_3 :Number of frame spaces, see Table 8.

4.4.7 Method 2 for vertical shear force adjustment at both bulkheads

The required adjustments in shear force at both transverse bulkheads of the mid-hold are to be made by applying:

- Vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends and,
- Vertical loads at the transverse frame positions as shown in Table 7 in order to generate vertical shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions.
- For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Table 7:
  - $\delta w'_1$: for aft most cargo hold model
  - $\delta w'_3$: for foremost cargo hold model

Table 6 shows examples of the shear adjustment application due to the vertical bending moments and to vertical loads.

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-fwd} - Q_{fwd})$$

$$M_{Y_aft} = \frac{X_{fore} - X_{aft}}{2} \cdot \frac{Q_{targ-fwd} - Q_{fwd} + Q_{targ-aft} - Q_{aft}}{2}$$

$$M_{Y_fore} = M_{Y_aft}$$

$$\Delta Q_{fwd} = \frac{Q_{targ-fwd} - Q_{fwd} - (Q_{targ-aft} - Q_{aft})}{2}$$

$$\Delta Q_{aft} = -\Delta Q_{fwd}$$

- Aft most cargo hold model

$$\delta w'_1 = \left(\frac{(Q_{targ-aft} - Q_{aft})(l - l_2 - l_1) + (Q_{targ-fwd} - Q_{fwd})(l - l_2 - l_3)}{(2l - l_1 - 2l_2 - l_3)} + R_{v_aft} \right) \frac{1}{(n_1 - 1)}$$

- Foremost cargo hold model

$$\delta w'_3 = \left(\frac{(Q_{targ-fwd} - Q_{fwd})(l - l_2 - l_3) + (Q_{targ-aft} - Q_{aft})(l - l_2 - l_1)}{(2l - l_1 - 2l_2 - l_3)} + R_{v_fore} \right) \frac{1}{(n_3 - 1)}$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model axis.

ΔQ_{aft} : Adjustment of shear force, in kN, at aft bulkhead of mid-hold.

ΔQ_{fwd} : Adjustment of shear force, in kN, at fore bulkhead of mid-hold.

M'_2 : Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- Aftmost cargo hold model $M'_2 = \frac{l_1 (n_1 - 1) \delta w'_1}{4}$
- Foremost cargo hold model $M'_2 = \frac{l_3 (n_3 - 1) \delta w'_3}{4}$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.

$\delta w'_3$: Distributed load, in kN, at frame in the the modelled forepeak of foremost cargo hold model, see also Table 8.

R_{v_aft}, M_{v_fore}: Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].

l_1 : Length of the modelled engine room in aftmost cargo hold model, in m. See also Table 8.

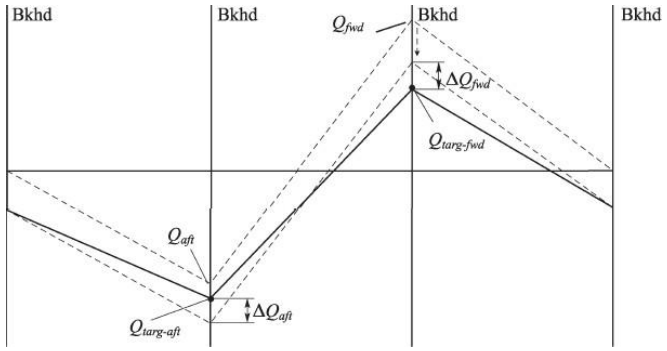
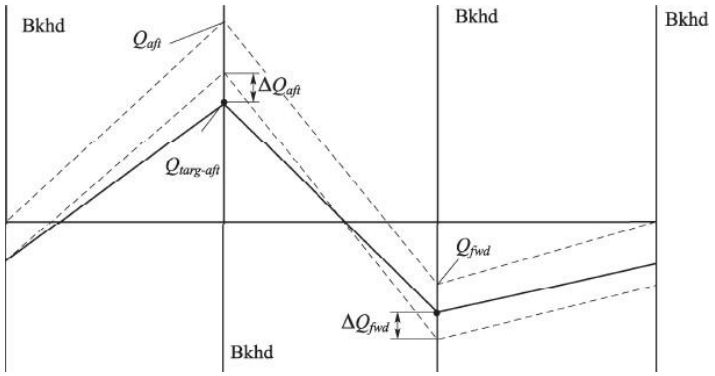
l_3 : Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.

$n_{1,3}$: Number of frame spaces, see Table 8.

The above adjustments in shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions are to be generated by applying vertical loads at the transverse frame positions as shown in Table 7. For bulk carriers, the transverse frame positions correspond to the floors. Vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward cargo hold and any frames aft of the aft cargo hold of the FE model.

The vertical loads to be applied to each transverse frame to generate the increase/decrease in shear force at the bulkheads may be calculated as shown in Table 7. In case of uniform frame spacing, the amount of vertical force to be distributed at each transverse frame may be calculated in accordance with Table 8.

Target and required shear force adjustment by applying vertical forces Table 6

Vertical shear force diagram	Aft Bhd	Fore Bhd
	SF target	SF target
	$Q_{targ\text{-}aft}$ *(-ve)*	$Q_{targ\text{-}fwd}$ *(+ve)*
	$Q_{targ\text{-}aft}$ *(+ve)*	$Q_{targ\text{-}fwd}$ *(-ve)*

Vertical shear force after both adjustment

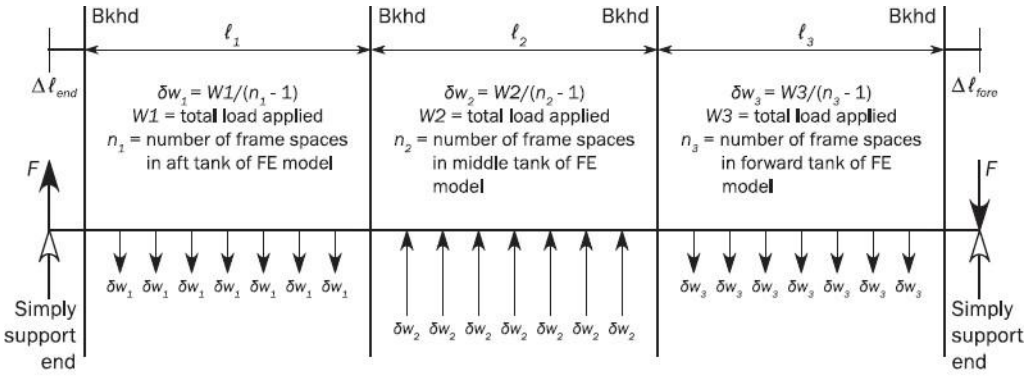
Vertical shear force after adjustment by use of M_{Y_aft} and M_{Y_fore}

Vertical shear due to local loads

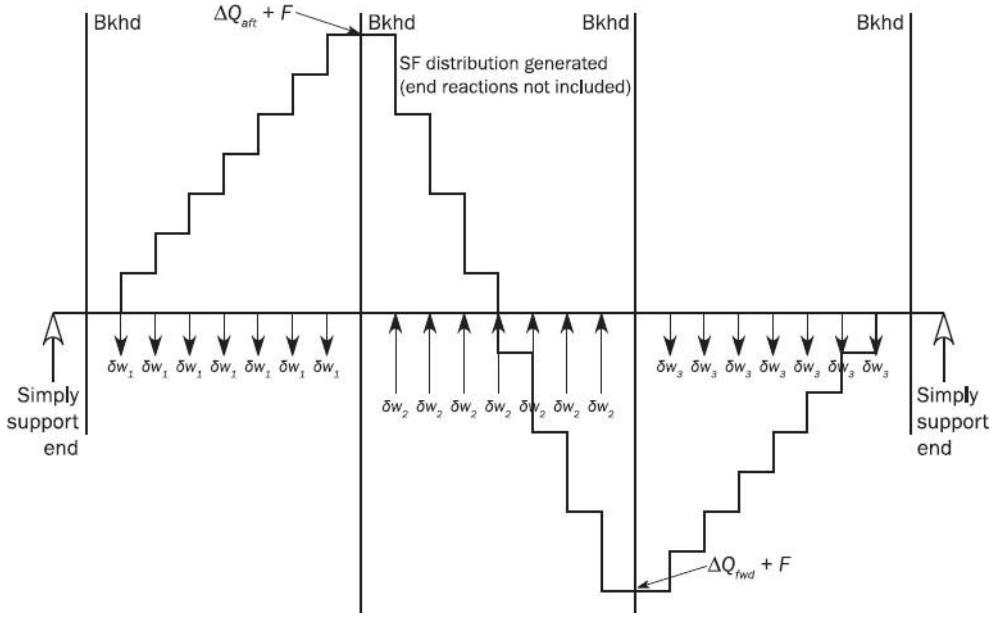
Note1: -ve means negative.
Note2: +ve means positive.

Distribution of adjusting vertical force at frames and resulting shear force distribution

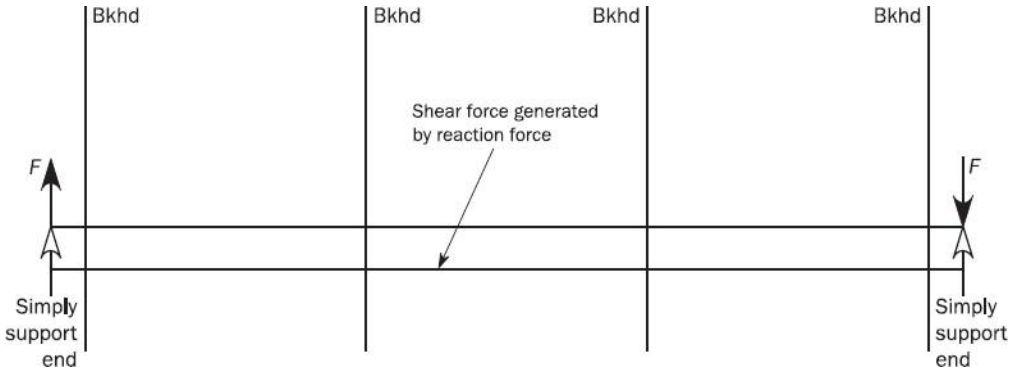
Table 7



Note: Transverse bulkhead frames not loaded
Frames beyond aft transverse bulkhead of aft most tank and forward bulkhead of forward most tank not loaded
F = Reaction load generated by supported ends



Shear Force distribution due to adjusting vertical force at frames



Note: F=0 if l_1=l_3 and l_{fore}=l_{end}, and loads are symmetrical about mid-length of model.

Note1: For definition of symbols, see Table 8.

Formulae for calculation of vertical loads for adjusting vertical shear forces Table 8

$$\delta w_1 = \frac{\Delta Q_{aft}(2l - l_2 - l_3) + \Delta Q_{fwd}(l_2 + l_3)}{(n_1 - 1)(2l - l_1 - 2l_2 - l_3)} + \delta w'_1$$

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

$$\delta w_3 = \frac{-\Delta Q_{fwd}(2l - l_1 - l_2) - \Delta Q_{aft}(l_1 + l_2)}{(n_3 - 1)(2l - l_1 - 2l_2 - l_3)} - \delta w'_3$$

In general

$$F = F_{aft} = F_{fwd} = 0.5\left[\frac{W1(l_2 + l_1) - W3(l_2 + l_3)}{l}\right]$$

For aftmost and foremost cargo hold FE model

$$F = F_{aft} = \left(\frac{W1(\Delta l_{fore} + l_3 + l_2 + 0.5l_1) + W2(\Delta l_{fore} + l_3 + 0.5l_2) + W3(\Delta l_{fore} + 0.5l_3)}{l}\right)$$

where:

l_1 : Length of aft cargo hold of model, in m.
l_2 : Length of mid-hold of model, in m.
l_3 : Length of forward cargo hold of model, in m.
ΔQ_{aft} : Required adjustment in shear force, in kN, at aft bulkhead of middle hold, see [4.4.7].
ΔQ_{fwd} : Required adjustment in shear force, in kN, at fore bulkhead of middle hold, see [4.4.7].
F : End reactions, in kN, due to application of vertical loads to frames.
$W1$: Total evenly distributed vertical load, in kN, applied to aft hold of FE model, $(n_1 - 1)\ \delta w_1$.
$W2$: Total evenly distributed vertical load, in kN, applied to mid-hold of FE model, $(n_2 - 1)\ \delta w_2$.
$W3$: Total evenly distributed vertical load, in kN, applied to forward hold of FE model, $(n_3 - 1)\ \delta w_3$.
n_1 : Number of frame spaces in aft cargo hold of FE model.
n_2 : Number of frame spaces in mid-hold of FE model.
n_3 : Number of frame spaces in forward cargo hold of FE model.
δw_1 : Distributed load, in kN, at frame in aft cargo hold of FE model.
δw_2 : Distributed load, in kN, at frame in mid-hold of FE model.
δw_3 : Distributed load, in kN, at frame in forward cargo hold of FE model.
$\delta w'_1$: Additional distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model. Formulae of $\delta w'_1$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.
$\delta w'_3$: Additional distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model. Formulae of $\delta w'_3$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.
Δl_{end} : Distance, in m, between end bulkhead of aft cargo hold to aft end of FE model.
$\Delta l_{end} = 0$ in the aftmost cargo hold model
Δl_{fore} : Distance, in m, between fore bulkhead of forward cargo hold to forward end of FE model.
$\Delta l_{fore} = 0$ in the foremost cargo hold model
l : Total length, in m, of FE model including portions beyond end bulkheads:
$= l_1 + l_2 + l_3 + l_4 + \Delta l_{end} + \Delta l_{fore}$

Note1: Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with Table 6 and Table 7.
Note2: $W1 + W3 = W2$. (not applicable for aftmost and foremost cargo FE model).
Note3: The above formulae are only applicable if uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.

If non-uniform frame spacing is used within each cargo hold, the average frame spacing $l_{av\text{-}i}$ is used to calculate the average distributed frame loads *wav-i,*, according to Table 8, where $i = 1, 2, 3$ for each hold.

Then $\delta w_{av\text{-}i}$ is redistributed to the non-uniform frame as follows:

$$\delta w_i^k = \delta w_{av-i} \frac{l_{av-i}^k}{l_{av-i}} \quad k=1, 2, \ldots, n_i - 1 \text{ for each frame in cargo hold i, i=1, 2, 3}$$

where:

$l_{av\text{-}i}$: Average frame spacing, in m, calculated as l_i / n_i, in cargo hold i with i = 1, 2, 3.
l_i : Length, in m, of the cargo hold i with i = 1, 2, 3 as defined in Table 8.
n_i : Number of frame spacing in cargo hold i with i = 1, 2, 3 as defined in Table 8.
$\delta w_{av\text{-}i}$: Average uniform frame spacing, in m, distributed force calculated according to Table 8 with the average frame spacing $l_{av\text{-}i}$ in cargo hold i with i = 1, 2, 3.
δw_i^k : Distributed load, in kN, for non-uniform frame k in cargo hold i.
$l^k_{av\text{-}i}$: Equivalent frame spacing, in m, for each frame k with k = 1, 2,..., ni - 1, in cargo hold i, taken as:

$$l^k_{av-i} = l^1_i - \frac{l_{av-i} l^1_i}{l^1_i + l^{n_i}_i} + \frac{l^2_i}{2} \quad \text{for } k = 1 \text{ (first frame), in cargo hold } i$$

$$l^k_{av-i} = \frac{l^k_i}{2} + \frac{l^{k+1}_i}{2} \quad \text{for } k = 2, 3, \ldots, n_1 - 2, \text{ in cargo } i$$

$$l^k_{av-i} = l^{n_i}_i - \frac{l_{av-i} l^{n_i}_i}{l^1_i + l^{n_i}_i} + \frac{l^{n_i-1}_i}{2} \quad \text{for } k = n_i - 1 \text{ (last frame), in cargo } i$$

l^k_i: Frame spacing, in m, between the frame k - 1 and k in the cargo hold i:

The required vertical load δw_i for a uniform frame spacing or $\delta_{wi}{}^k$ for non-uniform frame spacing, are to be applied by following the shear flow distribution at the considered cross section, as described in Ch 5, App 1. For a frame section under vertical load δw_i, the shear flow, q_f, at the middle point of the element is calculated as:

$$q_{f-k} = \frac{\delta w_i}{I_{y-n50}} Q_{k-n50}$$

where:
$q_{f\text{-}k}$: Shear flow calculated at the middle of the k-th element of the transverse frame, in N/mm.
δw_i : Distributed load at each transverse frame location for i-th cargo hold, i = 1, 2, 3, as defined in Table 8, in N.
$I_{y\text{-}n50}$: Moment of inertia of the hull girder cross section, in mm^4.
$Q_{k\text{-}n50}$: First moment about neutral axis of the accumulative section area starting from the open end (shear stress free end) of the cross section to the point sk for shear flow $q_{f\text{-}k}$ in mm^3, taken as;

$$Q_{k-n50} = \int_0^{S_k} z_{neu} t_{n50} \mathrm{d}s$$

z_{neu} : Vertical distance from the integral point, s, to the vertical neutral axis.
t_{n50} : Net thickness, in mm, of the plate at the integral point of the cross section.

The distributed shear force at j-th FE grid of the transverse frame, $F_{j\text{-}grid}$, is obtained from the shear flow of the connected elements as following:

$$F_{j-grid} = \sum_{k=1}^{n} q_{f-k} \frac{l_k}{2}$$

where:
l_k : Length of the k-th element of the transverse frame connected to the grid j, in mm.
n : Total number of elements connect to the grid j.

The shear flow has direction along the cross section and therefore the distributed force, $F_{j\text{-}grid}$, is a vector force. For vertical hull girder shear correction, the vertical and horizontal force components calculated with above mentioned shear flow method need to be applied to the cross section.

4.4.8 Procedure to adjust vertical and horizontal bending moments for midship cargo hold region

In case the target vertical bending moment needs to be reached, an additional vertical bending moment is to be applied at both ends of the cargo hold FE model to generate this target value in the mid-hold of the model. This end vertical bending moment is given as follows:

$M_{v\text{-}end} = M_{v\text{-}targ} - M_{v\text{-}peak}$

where:
$M_{v\text{-}end}$: Additional vertical bending moment, in kNm, to be applied to both ends of FE model in

accordance with [4.4.10].

$M_{v\text{-}targ}$: Hogging (positive) or sagging (negative) vertical bending moment, in kNm, as specified in [4.3.2].

$M_{v\text{-}peak}$:Maximum or minimum bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3] and due to the shear force adjustment as defined in [4.4.5].

$M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative). $M_{v\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{v-peak} = Extremum\left\{ M_{v_FEM}(x) + M_{lineload} + M_{Y_aft}\left(2\frac{x - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right\}$$

$M_{V_FEM(x)}$: Vertical bending moment, in kNm, at position x, due to the local loads as described in [4.4.3].

M_{Y_aft} : End bending moment, in kNm, to be taken as:

- When method 1 is applied: the value as defined in [4.4.6].
- When method 2 is applied: the value as defined in [4.4.7].
- Otherwise: $M_{Y_af} = 0$

$M_{lineload}$: Vertical bending moment, in kNm, at position x, due to application of vertical line loads at frames according to method 2, to be taken as:

$M_{lineload} = -(x - x_{aft})F - \sum_i (x - x_i)\,\delta w_i$ when $x_i < x$

F : Reaction force, in kN, at model ends due to application of vertical loads to frames as defined in Table 7.

x : X-coordinate, in m, of frame in way of the mid-hold.

δw_i : vertical load, in kN, at web frame station i applied to generate required shear force.

$\delta w_i = -\delta w_1$ when frame i is within after hold

$\delta w_i = \delta w_2$ when frame i is within mid-hold

$\delta w_i = -\delta w_3$ when frame i is within forward hold

In case the target horizontal bending moment needs to be reached, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate this target value within the mid-hold. The additional horizontal bending moment is to be taken as:

$$M_{h-end} = M_{h\text{-}targ} - M_{h-peak}$$

where:

$M_{h\text{-}end}$: Additional horizontal bending moment, in kNm, to be applied to both ends of the FE model according to [4.4.10].

$M_{h\text{-}targ}$: Horizontal bending moment, as defined in [4.3.4].

$M_{h\text{-}peak}$: Maximum or minimum horizontal bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3].

$M_{h\text{-}peak}$ is to be taken as the maximum horizontal bending moment if $M_{h\text{-}targ}$ is positive (starboard side in tension) and as the minimum horizontal bending moment if $M_{h\text{-}targ}$ is negative (port side in tension).

$M_{h\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{h-peak} = Extremum\left\{ M_{H_FEM}(x)\right\}$$

$M_{H_FEM\ (x)}$: Horizontal bending moment, in kNm, at position x, due to the local loads as described in [4.4.3].

The vertical and horizontal bending moments are to be calculated over the length of the mid-hold to identify the position and value of each maximum/minimum bending moment.

4.4.9 Procedure to adjust vertical and horizontal bending moments outside midship cargo hold region

To reach the vertical hull girder target values at each frame and transverse bulkhead position, as defined in [4.3.2], the vertical bending moment adjustments, *mvi*, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The vertical bending moment adjustment at each longitudinal location, *i*, is to be calculated as follows:

$$f(i) = M_{v\text{-}targ}(i) - M_{v\text{-}FEM}(i) - M_{lineload}(i) - M_{Y_aft}\left(2 \cdot \frac{x_i - x_{aft}}{x_{fore} - x_{aft}} - 1\right)$$

$$m_{vi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{vj}$$

$$m_{v-end} = -\sum_{j=0}^{n_t} m_{vj}$$

where:

i : Index corresponding to the i-th station, starting from i =1 at the aft end section up to n_t

n_t : Total number of longitudinal stations where the vertical bending moment adjustment, m_{vi}, is applied.

m_{vi} : Vertical bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station i.

m_{v_end} : Vertical bending moment adjustment, in kNm, to be applied, at the fore end section (n_t+1 station).

m_{vj} : Argument of summation to be taken as:

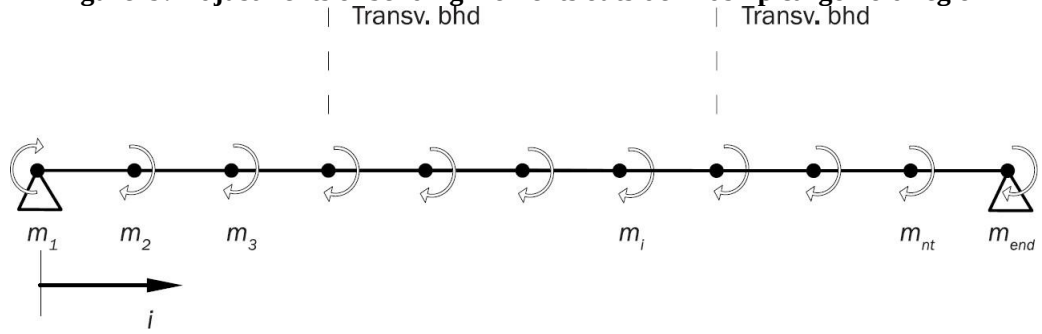
- m_{vo}= 0 when j=0
- m_{vj} = m_{vi} when j=i

$M_{v\text{-}targ(i)}$: Required target vertical bending moment, in kNm, at station i, calculated in accordance with [4.3.2].

$M_{V\text{-}FEM(i)}$: Vertical bending moment distribution, in kNm, at station i due to local loads as given in [4.4.3].

$M_{lineload(i)}$:Vertical bending moment, in kNm, at station i, due to the line load for the vertical shear force correction as required in [4.4.8].

Figure19: Adjustments of bending moments outside midship cargo hold region



m_{hi} can be substituted to m_{vi} in this figure and m_i is the positive bending moment in FE coordinate system.

To reach the horizontal hull girder target values at each frame and transverse bulkhead position as defined in [4.3.4], the horizontal bending moment adjustments, *mhi*, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The horizontal bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = M_{h\text{-}targ}(i) - M_{H-FEM}(i)$$

$$m_{hi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{hj}$$

$$n_t$$

$$m_{h-end} = -\sum_{j=0} m_{hj}$$

where:

i : Longitudinal location for bending moment adjustments, m_{hi}.

n_t : Total number of longitudinal stations where the horizontal bending moment adjustment, m_{hi}, is applied.

m_{hi} : Horizontal bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station i.

m_{h_end} :Horizontal bending moment adjustment, in kNm, to be applied at the fore end section (nt+1 station).

m_{hj} :Argument of summation to be taken as:

- m_{ho} = 0 when $j=0$
- $m_{hj} = m_{hi}$ when $j=i$

$M_{h\text{-}targ(i)}$: Required target horizontal bending moment, in kNm, at station i, calculated in accordance with [4.3.4].

$M_{H\text{-}FEM(i)}$: Horizontal bending moment distribution, in kNm, at station i due to local loads as given in [4.4.3].

The vertical and horizontal bending moment adjustments, m_{vi} and m_{hi}, are to be applied at all web frames and bulkhead positions of the FE model. The adjustments are to be applied in FE model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements in accordance with [4.4.10].

4.4.10 Application of bending moment adjustments on the FE model

The required vertical and horizontal bending moment adjustments are to be applied to the considered cross section of the cargo hold model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements of the considered cross section according to Ch 5, Sec 1, [1.2] as follows:

- For *vertical* bending moment:

$$(F_x)_i = \frac{M_v}{I_{y-n50}} \frac{M_{i-n50}}{n_i} z_i$$

- For *horizontal* bending moment:

$$(F_x)_i = \frac{M_h}{I_{z-n50}} \frac{A_{i-n50}}{n_i} y_i$$

where:

M_v : Vertical bending moment adjustment, in kNm, to be applied to the considered cross section of the model.

M_h : Horizontal bending moment adjustment, in kNm, to be applied to the considered cross section the ends of the model.

$(F_x)_i$: Axial force, in kN, applied to a node of the i-th element.

$I_{y\text{-}n50}$: Hull girder vertical moment of inertia, in m^4, of the considered cross section about its horizontal neutral axis.

$I_{z\text{-}n50}$: Hull girder horizontal moment of inertia, in m^4, of the considered cross section about its vertical neutral axis.

Z_i : Vertical distance, in m, from the neutral axis to the centre of the cross sectional area of the i-th element.

Y_i : Horizontal distance, in m, from the neutral axis to the centre of the cross sectional area of the i-th element.

$A_{i\text{-}n50}$: Cross sectional area, in m^2, of the i-th element.

n_i : Number of nodal points of i-th element on the cross section, n_i = 1 for beam element, n_i = 2 for 4- node shell element.

For cross sections other than cross sections at the model end, the average area of the corresponding i-th elements forward and aft of the considered cross section is to be used.

4.5 Procedure to adjust hull girder torsional moments

4.5.1 General

The procedure in this sub-article describes how to adjust the hull girder torsional moment distribution on the cargo hold FE model to achieve the target torsional moment at the target location. The hull girder torsional moment target values are given in [4.3.5].

4.5.2 Torsional moment due to local loads

Torsional moment, in kNm, at longitudinal station i due to local loads, $M_{T\text{-}FEMi}$ in kNm, is

determined by the following formula (see Figure 20):

$$M_{T-FEM_i} = \sum_k \left[f_{hik}(z_{ik} - z_r) \right] - \sum_k (f_{vik} y_{ik})$$

where:

$M_{T\text{-}FEMi}$: Lumped torsional moment, in kNm, due to local load at longitudinal station *i*.

z_r : Vertical coordinate of torsional reference point, in m:

For bulk carrier, $z_r = 0$.

For oil tanker, $z_r = z_{sc}$, shear centre at the middle of the mid-hold.

f_{hik} : Horizontal nodal force, in kN, of node *k* at longitudinal station *i*.

f_{vik} : Vertical nodal force, in kN, of node *k* at longitudinal station *i*.

y_{ik} : *Y*-coordinate, in m, of node *k* at longitudinal station *i*.

z_{ik} : *Z*-coordinate, in m, of node *k* at longitudinal station *i*.

$M_{T\text{-}FEM0}$: Lumped torsional moment, in kNm, due to local load at aft end of the FE model (forward end for foremost cargo hold model), taken as:

$$M_{T-FEM0} = -\sum_k [f_{h0k}(z_{0k} - z_r)] + \sum_k (f_{v0k} y_{0k}) + R_{H_fwd} \cdot (z_{ind} - z_r) \quad \text{for foremost cargo hold model}$$

$$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_r)] - \sum_k (f_{v0k} y_{0k}) + R_{H_aft} \cdot (z_{ind} - z_r) \quad \text{for the other cargo hold models}$$

R_{H_fwd} : Horizontal reaction forces, in kN, at the forward end, as defined in [4.4.3].

R_{H_aft} : Horizontal reaction forces, in kN, at the aft end, as defined in [4.4.3].

z_{ind} : Vertical coordinate, in m, of independent point as defined in [2.5.3].

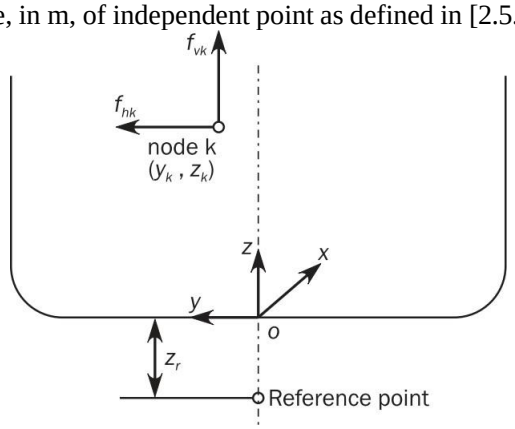


Figure20 Station forces and acting location of torsional moment at section

4.5.3 Hull girder torsional moment

The hull girder torsional moment, $M_{T\text{-}FEM}$ (x_j) in kNm, is obtained by accumulating the station torsional moment from the aft end section (forward end for foremost cargo hold model) as follows:

$$M_{T-FEM}(x_j) = \sum_i M_{T-FEMi}$$

- when $x_i \geqslant x_j$ for foremost cargo hold model,
- when $x_i < x_j$ otherwise.

where:

$M_{T\text{-}FEM}$ (x_j): Hull girder torsional moment, in kNm, at longitudinal station x_j.

x_j : *X*-coordinate, in m, of considered longitudinal station *j*.

The torsional moment distribution given in [4.5.2], has a step at each longitudinal station.

4.5.4 Procedure to adjust hull girder torsional moment to target value

The torsional moment is to be adjusted by applying a hull girder torsional moment $M_{T\text{-}end}$ in kNm, at the independent point of the aft end section of the model (forward end for foremost cargo hold model), given as follows:

$$M_{T-end} = M_{wt\text{-}targ} - M_{wt}(x_{targ})$$

where:

x_{targ} : *X*-coordinate, in m, of the target location for hull girder torsional moment, as defined in

[4.3.5].

$M_{wt\text{-}targ}$: Target hull girder torsional moment, in kNm, specified in [4.3.5], to be achieved at the target location.

$M_{T\text{-}FEM}\,(x_{targ})$: Hull girder torsional moment, in kNm, at target location due to local loads.

Due to the step of hull girder torsional moment at each longitudinal station, the hull girder torsional moment is to be selected from the values aft and forward of the target location as follows: Maximum value for positive torsional moment and minimum value for negative torsional moment.

4.6 Summary of hull girder load adjustments

4.6.1

The required methods of hull girder load adjustments for different cargo hold regions are given in Table 9.

Overview of hull girder load adjustments in FE analyses **Table 9**

	Midship cargo hold region	After and Forward cargo hold region	Aft most cargo holds	Foremost cargo holds
Adjustment of Vertical Shear Forces	See [4.4.5]			
Adjustment of Bending Moments	See [4.4.8]	See [4.4.9]		
Adjustment of Torsional Moment	See [4.5.4]			

5 ANALYSIS CRITERIA

5.1 General

5.1.1 Evaluation areas

Verification of results against the acceptance criteria is to be carried out within the longitudinal extent of the mid-hold, as shown in Figure 21 and Figure 22.

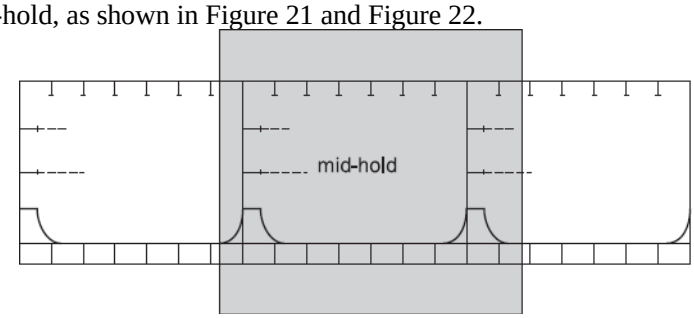


Figure21 Longitudinal extent of evaluation area for oil tanker

5.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [5.2] and [5.3]:

- All hull girder longitudinal structural members,
- All primary supporting structural members and bulkheads within the mid-hold,
- All structural members being part of the transverse bulkheads, such as:
- For oil tanker: stringer, buttress structure, stool tanks, partial girders together with attached transverse structures,
- For bulk carrier: stool tanks together with connected longitudinal girders and double bottom floors,
- All structural members being part of the collision bulkhead, and extending to one web frame spacing forward of the collision bulkhead,
- All structural members being part of the forward transverse bulkhead of the machinery space and all hull girder longitudinal structural members aft of this transverse bulkhead within the extent of 15% of the aftmost cargo hold length excluding slop tanks.

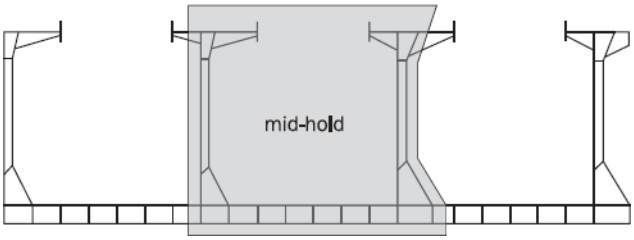


Figure 22 Longitudinal extent of evaluation area for bulk carrier

5.2 Yield strength assessment

5.2.1 Von Mises stress

For all plates of the structural members defined in [5.1.2], the von Mises stress, σ_{vm}, in N/mm^2, is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid-plane (layer), as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

σ_x, σ_y : Element normal membrane stresses, in N/mm^2.

τ_{xy} : Element shear stress, in N/mm^2.

5.2.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress, σ_{axial}, in N/mm^2, is to be calculated based on axial force alone. The axial stress is to be evaluated at the middle of element length.

5.2.3 Coarse mesh permissible yield utilisation factors

The coarse mesh permissible yield utilisation factors, λ_{yperm}, given in Table 10, are based on the mesh sizes and element types described in [2.3] to [2.4].

The yield utilisation factor resulting from element stresses of each structural component are not to exceed the permissible values as given in Table 10.

Coarse mesh permissible yield utilisation factor **Table 10**

Structural component	Coarse mesh permissible yield utilisation factor, λ_{yperm}
Plating of all longitudinal hull girder structural members, primary supporting structural members and bulkheads. Face plate of primary supporting members modelled using shell or rod elements. Dummy rod of corrugated bulkhead	1.0 (load combination S+D) 0.8 (load combination S)
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool (1).	0.90 (load combination S+D) 0.72 (load combination S)
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads and without lower stool, for shell elements only.	0.81 (load combination S+D) 0.65 (load combination S)

1) Supporting structure for a transverse corrugated bulkhead refers to the structure in the longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth.
Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within 3 longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.

5.2.4 Yield criteria

The structural elements given in [5.1.2] are to comply with the following criteria:

$\lambda_y \leqslant \lambda_{ype\ rm}$

where:
λ_y : yield utilisation factor.

$$\lambda_y = \frac{\sigma_{vm}}{R_y} \text{ for shell elements in general.}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_y} \text{ for rod or beam elements in general.}$$

σ_{vm} : Von Mises stress, in N/mm^2.
σ_{axial} : Axial stress in rod or beam element, in N/mm^2.
λ_{yperm} : Coarse mesh permissible yield utilisation factors defined in Table 10.

The yield check criteria is to be based on axial stress for the following members:

- The flange of primary supporting members,
- The intersections between the flange and web of the corrugations, according to [5.2.5].

Where the von Mises stress of the elements in the cargo hold FE model in way of the area under investigation by fine mesh exceeds the yield criteria, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo hold finite element model is to satisfy the yield criteria above.
In way of cut-outs, yield utilisation factor is to be obtained with shear stress correction, as given in [5.2.6].

5.2.5 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

a) The von Mises stress, σ_{vm}, in shell elements on the flange and web of the corrugation.
b) The axial stress, σ_{axial}, in dummy rod elements, modelled with unit cross sectional properties at the intersection between the flange and web of the corrugation.

5.2.6 Shear stress correction for cut-outs

Except as indicated in [5.2.7], the element shear stress in way of cut-outs in webs is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the yield criteria.

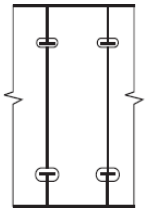
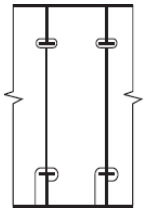
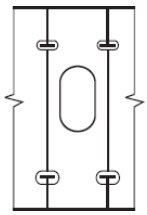
$$\tau_{cor} = \frac{ht_{mod-n50}}{A_{shr-n50}} \tau_{elem}$$

where:
τ_{cor} : Corrected element shear stress, in N/mm^2.
h : Height of web of girder, in mm, in way of opening, see Table 1. Where the geometry of the opening is modelled, h is to be taken as the height of web of the girder deducting the height of the modelled opening.
$t_{mod\text{-}n50}$: Modelled web thickness, in mm, in way of opening.
$A_{shr\text{-}n50}$: Effective net shear area of web, in mm^2, taken as the web area deducting the area lost of all openings, including slots for stiffeners, calculated in accordance with Ch 3, Sec 7, [1.4.8].
τ_{elem} : Element shear stress, in N/mm^2, before correction.

5.2.7 Exceptions for shear stress correction for openings

Correction of element shear stress due to presence of cut-outs is not required for cases given in Table 11 provided λ_y/C_r complies with the criteria given in [5.2.4].

Exceptions for shear stress correction **Table 11**

Identification	Figure	Difference between modelled shear area and the net effective shear area in % of the modelled shear area $\frac{A_{FEM-n50} - A_{shr-n50}}{A_{FEM-n50}} \cdot 100\%$	Reduction factor for yield criteria, C_r
Upper and lower slots for local support stiffeners fitted with lugs or collar plates		< 15%	0.85
Upper or lower slots for local support stiffeners fitted with lugs or collar plates		< 20%	0.80
In way of opening; upper and lower slots for local support stiffeners fitted with collar plates		< 40%	0.60
$A_{shr\text{-}n50}$: Effective net shear area of the web, in mm^2, taken as the web area without the all opening areas and without the slots for stiffeners, in accordance with Ch 3, Sec 7, [1.4.8].			

5.3 Buckling strength assessment

5.3.1

All structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 8, Sec 4.

Section 3 LOCAL STRUCTURAL STRENGTH ANALYSIS

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The local strength analysis of structural details is to be in accordance with the requirements given in this section.

1.1.2

The selection of critical locations on the structural members for fine mesh analysis is to be in accordance with this section.

1.1.3 Fine mesh analysis procedure

The details to be assessed by fine mesh analysis are to be modelled according to the requirements given in [4], under the FE load combinations defined in [5] and to comply with the criteria given in [6].

1.1.4 Scope of local structural strength verification

The fine mesh verification is to be performed as follows:

- Fine mesh analysis for the structural details given in [2],
- Screening procedure according to [3].

2 LOCAL AREAS TO BE ASSESSED BY FINE MESH ANALYSIS

2.1 List of mandatory structural details

2.1.1 List of structural details

In the midship cargo hold region, the following structural details are to be assessed according to the fine mesh analysis procedure defined in [1.1.3]:

a) Hopper knuckles for ship with double side as given in [2.1.2],
b) Side frame end brackets and lower hopper knuckle for single side bulk carrier as given in [2.1.3],
c) Large openings as given in [2.1.4],
d) Connections of deck and double bottom longitudinal stiffeners to transverse bulkhead as given in [2.1.5],
e) Connections of corrugated bulkhead to adjoining structure as given in [2.1.6].
f) Bracket at the heel of horizontal stringer as given in [2.1.7].

For each above mentioned structural detail, one fine mesh model is required within all the cargo hold models covering the midship cargo hold region. The selection of the location of this fine mesh model is to be based on requirements given from [2.1.2] to [2.1.7] from all cargo hold analyses in the midship cargo hold region.

2.1.2 Hopper knuckles for ship with double side

Fine mesh analysis is to be carried out for the lower and upper hopper knuckles of either welded or bent type, in way of a typical transverse web frame, as indicated in Figure 1.

For double side arrangements without the hopper plating, i.e. where the inner hull longitudinal bulkhead is fitted directly to the inner bottom, fine mesh analysis is to be carried out for the heel of the transverse web frame.

The transverse web frame which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in knuckle is to be selected for the fine mesh analysis.

2.1.3 Side frame end brackets and lower hopper knuckle for single side bulk carrier

Fine mesh analysis is to be carried out for the lower hopper knuckle of either welded or bent type, lower and upper end bracket of side frame, as indicated in Figure 2.

The side frame which in the cargo hold analysis has the maximum yield utilisation factor, λ_y , in end bracket joints is to be selected for the fine mesh analysis.

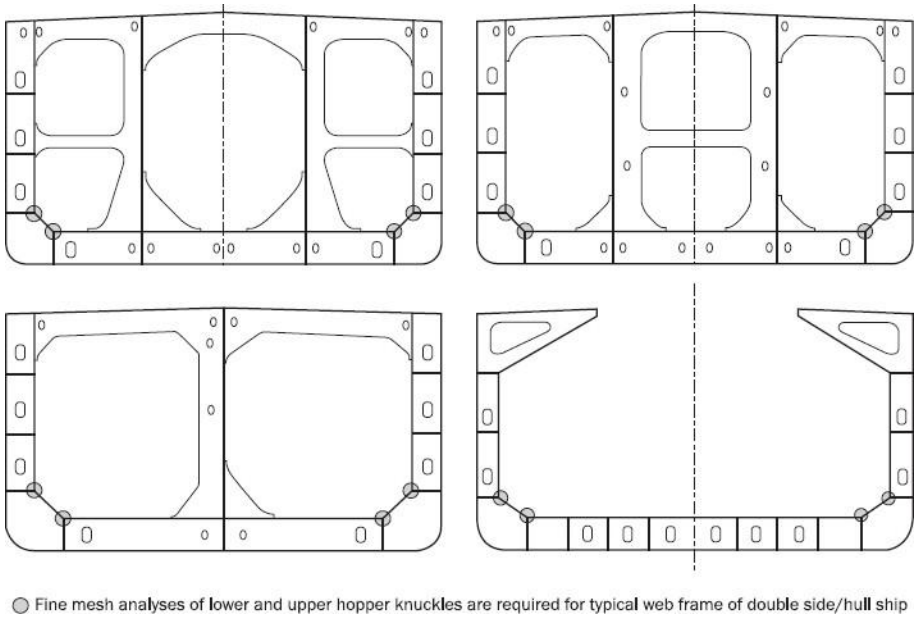


Figure 1 Mandatory areas at hopper knuckles for ships with double side

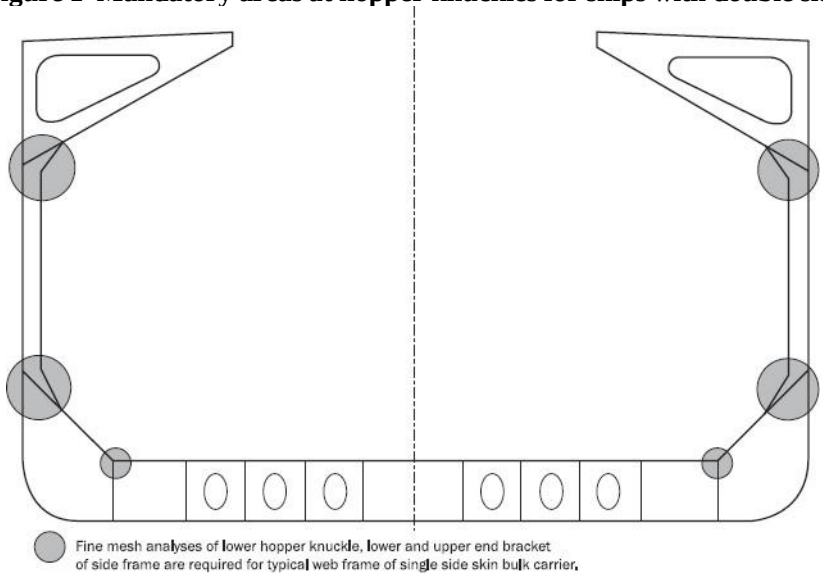


Figure 2 Mandatory areas at lower upper knuckle and side frame end brackets for single side bulk carrier

2.1.4 Large openings

Large openings in way of primary supporting members, for which their geometry is required to be represented in the cargo hold model in accordance with Ch 7, Sec 2, [2.4.9], are to be assessed by fine mesh analysis.

The structural member in way of the large openings having the maximum yield utilisation factor, λ_y , in the cargo hold analysis is to be selected for the fine mesh analysis.

2.1.5 Connections between deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead

Fine mesh analysis is to be carried out for the connections of deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead, either plane or corrugated bulkhead. The adjoining structures of transverse bulkhead include the structural members in way of the bulkhead, the partial deck girders and partial double bottom girders, if any.

For example, the following structural members are to be assessed, some of them being shown in Figure 3:

- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of transverse bulkhead.

- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of adjacent floor to the transverse bulkhead.
- At least one connection between deck longitudinal stiffener (fitted above or below deck) and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between deck longitudinal partial girder on top of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between bottom longitudinal partial girder in way of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.

The selection of the connections between longitudinal and vertical stiffeners to be analysed is to be based on the maximum relative deflection between supports, i.e. between floor and transverse bulkhead or between deck transverse and transverse bulkhead. Where there is a significant variation in end connection arrangement between stiffeners or scantlings, analyses of additional connections may be required by the Society.

Outside the midship cargo hold region, the scantlings of the connections as given above are not to be less than the required scantlings obtained for the midship cargo hold region unless an equivalent strength is demonstrated by fine mesh analysis.

ISC 2.1.5a Additional fine mesh analysis is to be carried out in the following cases:
Where there is a significant variation in the end connection arrangement between stiffeners or scantlings, e.g. a variation of the shape or arm length of the stiffener end connection bracket, the connecting structure with the maximum relative deflection between supports is to be selected from attached end connections for analysis.

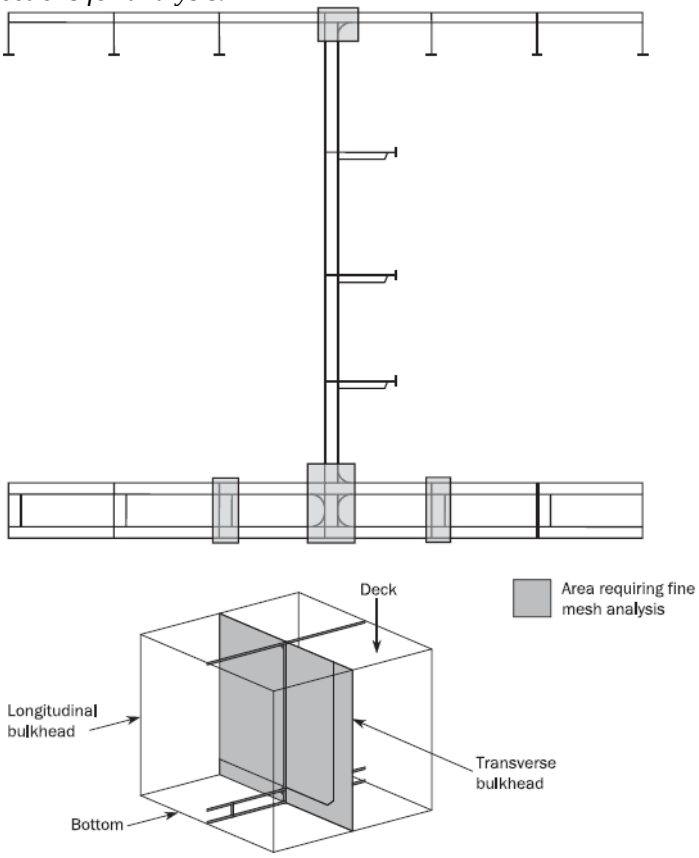


Figure 3 Examples of mandatory areas at connections between double bottom and deck longitudinals and adjoining structure of transverse bulkhead

2.1.6 Connections between corrugation and adjoining lower structure

Fine mesh analysis is to be carried out for connections between corrugation and adjoining lower supporting structures. For example, the following structural members, as shown in Figure 4, are to be assessed:

- Connection of the corrugation and supporting structure in way of lower stool shelf plate.
- Connection of the corrugation and lower supporting structure to inner bottom if no

lower stool is fitted.

- Connection of the corrugation and the upper corner of the gusset plate if shedder plate with a gusset plate is fitted at top of the lower stool.

The corrugation unit as defined in Ch 8, Sec 4, [3.3.2] which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in way of the corrugation connection, is to be selected for the fine mesh analysis.

Where there is a significant variation in the arrangement of supporting structure of the corrugation, analysis of additional locations may be required by the Society.

For ships with both longitudinal and transverse corrugated bulkheads, fine mesh analysis is required for the connection between corrugations and supporting structure in way of the lower stool shelf plate or inner bottom, if no lower stool is fitted, at the intersection between longitudinal and transverse corrugated bulkheads.

ISC 2.1.6a Additional fine mesh analysis is to be carried out in the following cases:

1) *For corrugation structure fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the diaphragm of lower stool, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the diaphragm of lower stool.*
2) *For longitudinal corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom floor, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom floor.*
3) *For transverse corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom girder, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom girder.*
4) *When the shape of the corrugation unit as defined in 3.3.2, Section 4, Chapter 8 of this PART is different from the one which has been selected for fine mesh analysis, the fine mesh analysis is to be carried out to the location with the maximum yield utilisation factor for areas of the corrugation units having a different shape respectively.*

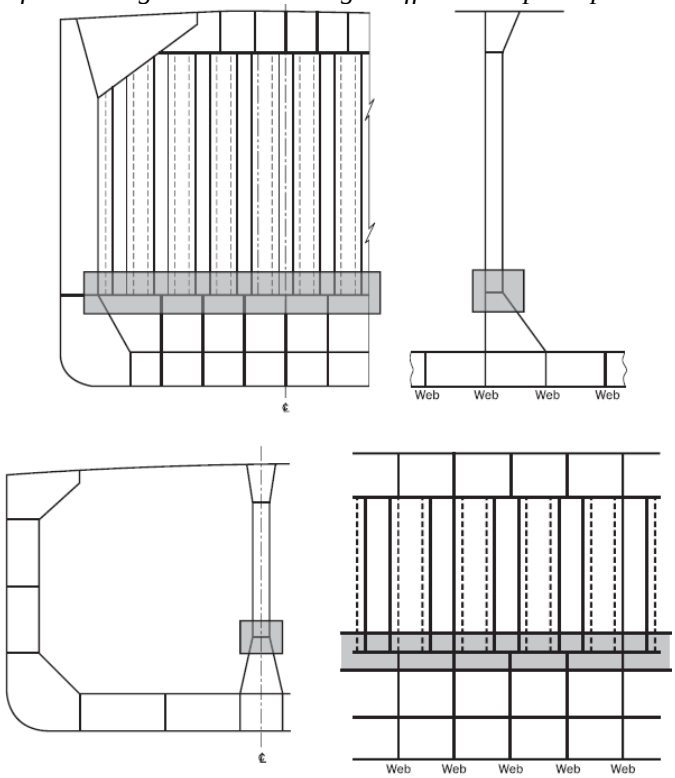


Figure 4 Mandatory areas at connections between corrugations and adjoining lower stool

2.1.7 Bracket at the heel of horizontal stringer

Fine mesh analysis is to be carried out for the bracket at the heel of horizontal stringers. All structural elements adjacent to the heel including the inner hull, longitudinal and transverse bulkhead are to satisfy the stress acceptance criteria. The heel of horizontal stringer which, in the cargo hold analysis, has the maximum yield utilization factor, λ_y, is to be selected for the fine mesh analysis. Where there is a significant variation in the arrangement of the bracket at the heel and the horizontal stringer, analysis of additional locations may be required by the Society.

3 SCREENING PROCEDURE

3.1 Screening areas

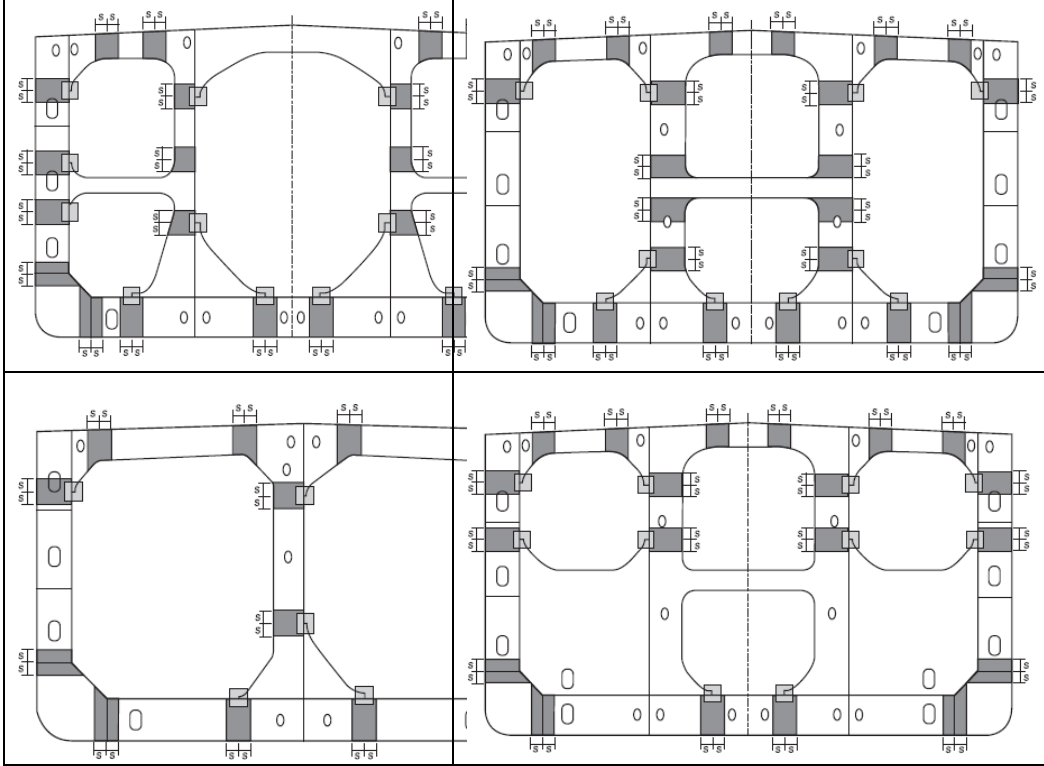
3.1.1

The structural details subject to this screening procedure are checked in the following ship areas:

3.1.1 Within the full cargo hold region for the details given in [3.2.1],

3.1.2 Outside midship cargo hold region for the details given in [3.2.2].

Screening areas of transverse web frame in oil tanker **Table 1**

<table>
<tr><td colspan="3">  </td></tr>
<tr><td></td><td>Bracket toes</td><td></td></tr>
<tr><td></td><td>Openings and manholes (shaded regions)</td><td></td></tr>
<tr><td></td><td>Openings and manholes (unshaded regions)</td><td>Screening check to be performed for openings except if:
h_0/h < 0.35 and g_0 < 1.2, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). This criterion does not apply to manholes which are to be evaluated by screening irrespective of size.
h_0, h and go is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.</td></tr>
</table>

3.2 List of structural details

3.2.1 Cargo hold region

The following structural details and areas in the cargo hold region are to be evaluated by screening:

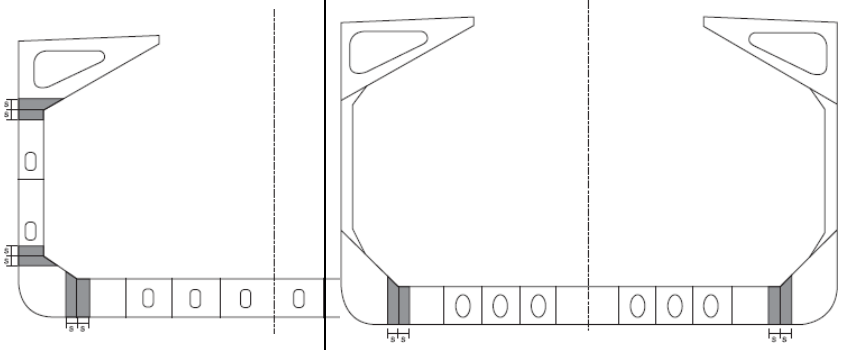
a) Openings which do not require modelling and manholes, see Ch 7, Sec 2, [2.4.9, in way of web of primary supporting members, such as transverse web frame as indicated in

Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.

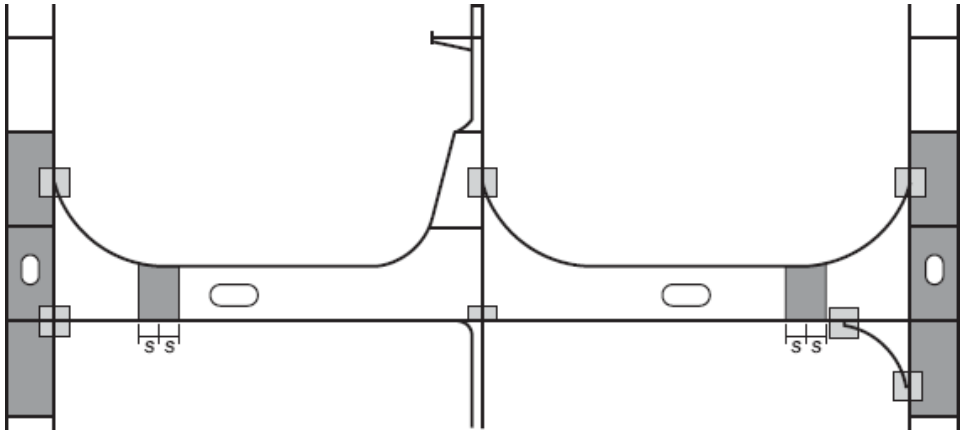
b) Bracket toes on transverse web frame as indicated in Table 1 and Table 2, horizontal stringer and transverse plane bulkhead connected to double bottom or buttress structure specified in Table 3.
c) Heels of transverse bulkhead horizontal stringers specified in Table 3.
d) Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5.
e) Connection of lower hopper to transverse lower stool structure as indicated in Figure 5.
f) Connection of topside tank to inner side as indicated in Figure 6.
g) Connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.
h) Hatch corner area, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection as indicated in Figure 8.

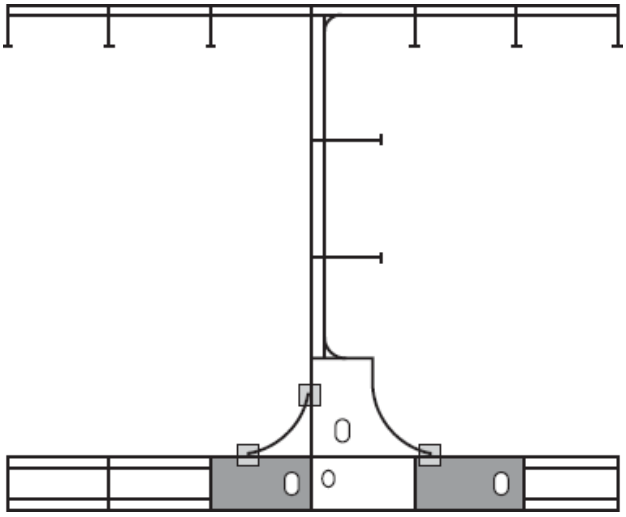
Within each group of the structural details having the same geometry and the same relative location inside the cargo region, the screening verification can be performed for the detail for which the yield utilisation factor, λ_y, is maximum.

Screening areas for transverse web frame in bulk carrier **Table 2**

<table>
<tr><td colspan="3">  </td></tr>
<tr><td></td><td colspan="2">Bracket toes</td></tr>
<tr><td></td><td colspan="2">Openings and manholes (shaded regions)</td></tr>
<tr><td></td><td>Openings and manholes (unshaded regions)</td><td>Screening check to be performed for openings except if:
$h_0/h < 0.35$ and $g_0 < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$)， This criterion does not apply to manholes which are to be evaluated by screening irrespective of size.
h_0, h and g_0 is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.</td></tr>
</table>

Screening areas for horizontal stringer and transverse bulkhead to double bottom connections in oil tanker **Table 3**





	Bracket toes and heels	
	Openings and manholes (shaded regions)	
	Openings and manholes (unshaded regions)	Screening check to be performed for openings except if: h_0/h < 0.35 and go < 1.2, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). . This criterion does not apply to manholes which are to be evaluated by screening irrespective of size. h_0, h and g_0 is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.

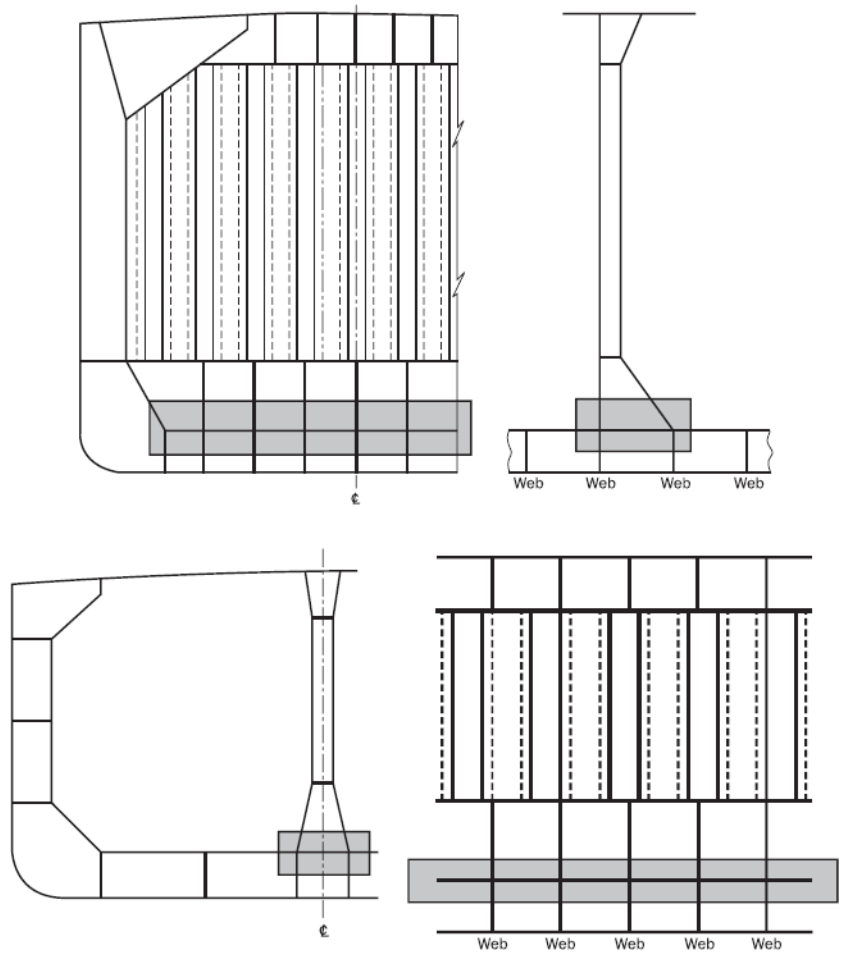


Figure 5 Screening areas at connections of lower stool to inner bottom and hopper tank

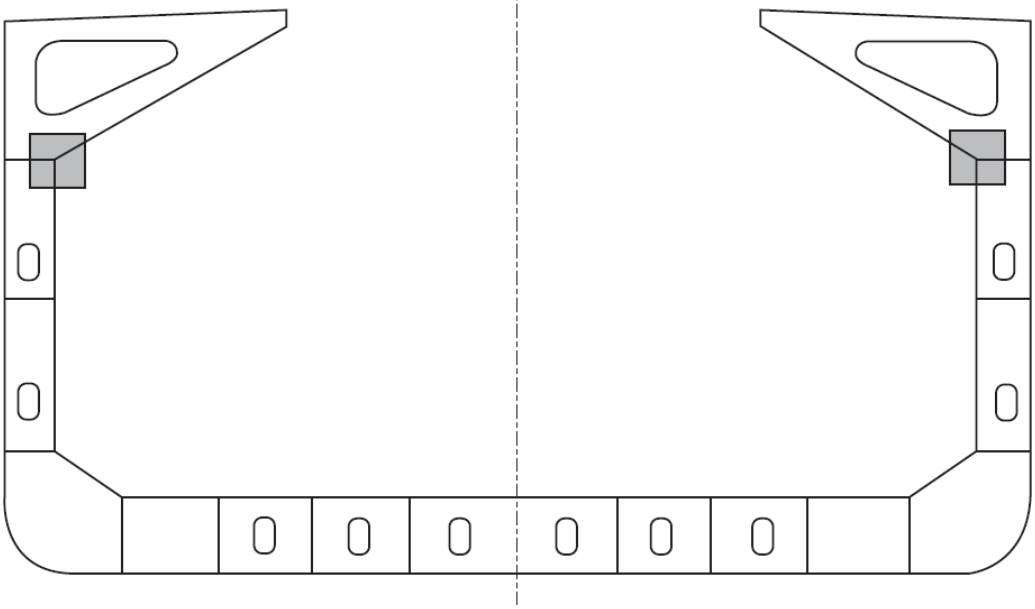


Figure 6 Screening areas at connections of topside tank to inner side

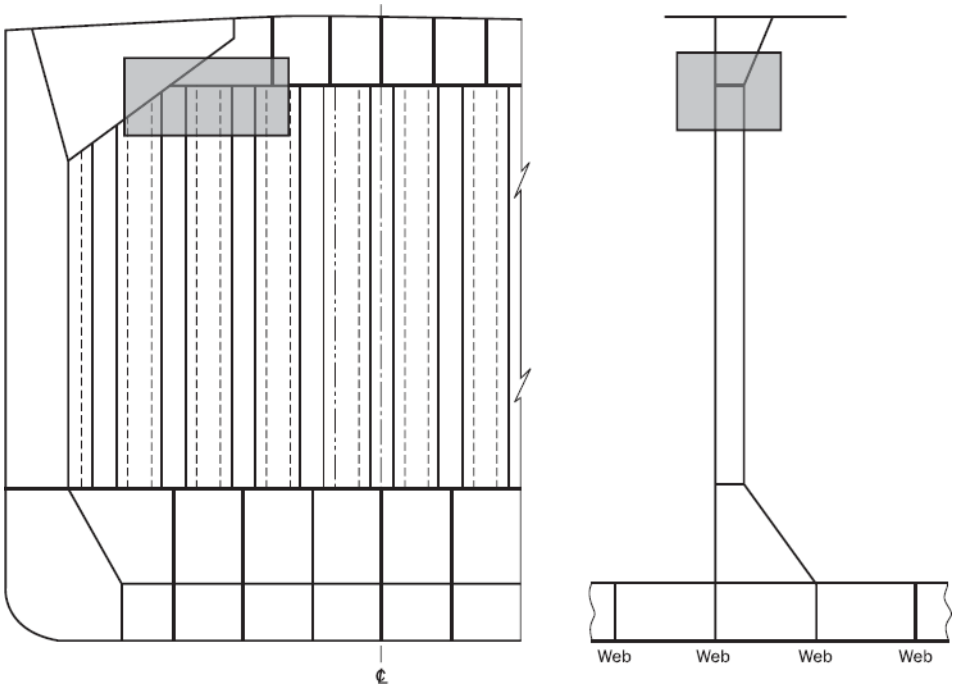


Figure 7 Screening areas at connection of corrugation and upper supporting structure to upper stool

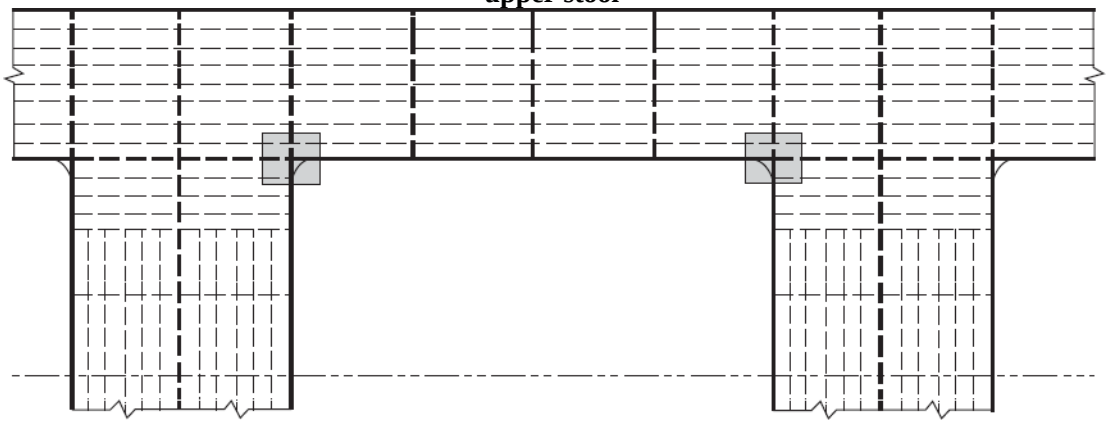


Figure 8 Screening areas at hatch corner in bulk carrier

3.2.2 Outside midship cargo hold region

The following structural details outside midship cargo hold region are to be evaluated by screening:

a) Hopper knuckle, as defined in [2.1.2] and [2.1.3],
b) Side frame end bracket, as defined in [2.1.3],
c) Large openings, as defined in [2.1.4],
d) Connections of corrugation to adjoining structure, as defined in [2.1.6],
e) Bracket at the heel of horizontal stringers in [2.1.7],
f) The connections of corrugation to adjoining structure and the bracket at the heel of horizontal stringers to be screened are to be similar in its geometry, its proportion and its relative location to the corresponding detail modelled in fine mesh in the midship cargo hold region.

When the connections of corrugation to adjoining structure and the bracket at the heel of horizontal stringers outside the midship cargo hold region are different from the corresponding detail modelled in fine mesh in the midship cargo hold region, a fine mesh analysis is to be performed for the detail located where the yield utilisation factor, λ_y, is maximum for structural details having the same geometry and the same relative location.

When it is deemed necessary, the Society may request a fine mesh analysis to be performed according to [1.1.3].

3.3 Screening criteria

3.3.1 Screening factors and permissible screening factors

The screening factors, λ_{sc}, and the permissible screening factors, λ_{scperm}, are given in Table 4 for the screening areas defined in [3.1].

Screening factors and permissible screening factors **Table 4**

Type of Details	Screening factors, λ_{sc}	Permissible screening factors, λ_{scperm}	
Within the whole cargo hold region		S+D	S
Openings for which their geometry is not required to be represented in the cargo hold model in accordance with Ch 7, Sec 2, [2.4.9] in way of webs of primary supporting members, such as transverse web frame as indicated in Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.	Table 5	1.70	1.36
Manholes (2)	λ_y	$0.85\lambda_{yperm}$	
Bracket toes on transverse web frames as indicated in Table 1 and Table 2, horizontal stringers and transverse plane bulkhead to double bottom connection or buttress structure specified in Table 3.	Table 6	1.50	1.20
Heels of transverse bulkhead horizontal stringers specified in Table 3.	Table 7	1.50	1.20
Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5. The connection of lower hopper to transverse lower stool structure as indicated in Figure 5. The connection of topside tank to inner side as indicated in Figure 6. The connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.	λ_y	$0.75\lambda_{yperm}$	
Hatch corner area.	λ_y	$0.95\lambda_{yperm}$	
Outside midship cargo hold region			
Hopper knuckle	$\lambda_{sc} = \frac{K_{sc} \cdot \sigma_c}{R_y}$ (1)	$0.65\ \lambda_{yperm}$ $0.65\lambda_{yperm}$	
Side frame end bracket		$0.85\lambda_{yperm}$ $0.85\lambda_{yperm}$	
Large openings (2)		$0.85\lambda_{yperm}$	
Connections of corrugation to adjoining structure and bracket at the heel of horizontal stringer		1.50 f_f	$1.20f_f$

where:

λ_y : Coarse mesh yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

λ_{yperm} : Coarse mesh permissible yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

K_{sc} : Screening stress concentration factor, taken as:

$$K_{sc} = \frac{\sigma_{FM}}{\sigma_{CM}}$$

σ_{FM} : Von Mises fine mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to [2].

σ_{CM} : Von Mises coarse mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to Ch 7, Sec 2.

σ_c : Von Mises coarse mesh stress, in N/mm^2, for the area in way of considered detail.

f_f : Fatigue factor defined in [6.2.1].

(1) For each screened detail, σ_{FM} and σ_{CM} are to be taken from the corresponding elements in the same plane position.

(2) The representative element which has maximum yield utilisation factor around the manhole and the large opening is to be verified against criterion.

Screening factor for openings in primary supporting members **Table 5**

λ_{sc} : Screening factor taken as

$$\lambda_{sc} = 0.85 C_h \left(\left| \sigma_x + \sigma_y \right| + \left(2 + \left(\frac{l_0}{2r}\right)^{0.74}\right) \left| \tau_{xy} \right| \right) \frac{k}{235}$$

C_h : Coefficient taken as (2):

- For opening in web of PSM.

$$C_h = 1.0 - 0.23\left(\frac{h_0}{h}\right) + 2.12\left(\frac{h_0}{h}\right)^2$$

- For opening in web of main bracket and buttress (see figures below).

C_h = 1.0

r : Radius of opening, in mm.

h_0 : Height of opening parallel to depth of web, in mm.

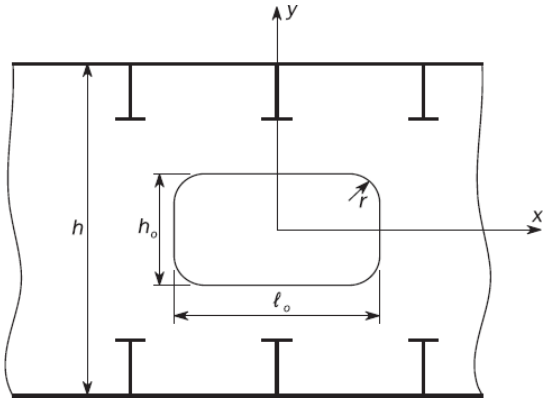
l_0 : Length of opening parallel to girder web direction, in mm.

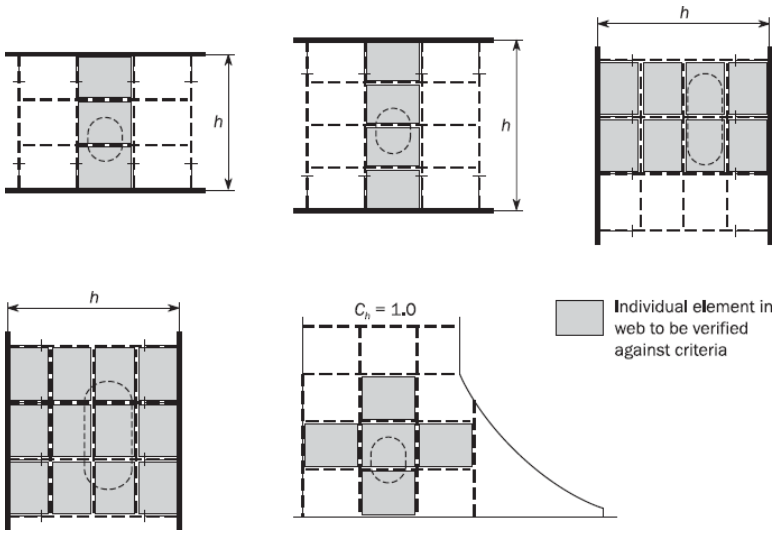
h : Height of web of girder in way of opening, in mm.

σ_x : Axial stress in element x-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm^2.

σ_y : Axial stress in element y-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm2.

σ_{xy} : Element shear stress determined from cargo hold FE analysis (1), in N/mm^2.





(1) The element shear stress is to be adjusted using the formula given in Ch 7, Sec 2, [5.2.6] prior to the evaluation of yield utilisation factor for verification against the screening criteria.

(2) Where the geometry of the opening is required to be modelled in accordance with Ch 7, Sec 2, [2.4.9], fine mesh FE analysis is to be carried out to determine the stress level and the screening criteria are not applicable.

Screening factor for bracket toes of primary supporting members **Table 6**

λ_{sc} : Screening factor taken as:

$$\lambda_{sc} = C_a \left(0.68(\frac{b_2}{b_1})^{0.5} \sigma_{vm} + 0.50(\frac{A_{beam-n50}}{b_1 t_{n50}})^{0.5} |\sigma_{beam}| \right) \frac{k}{235}$$

C_a : Coefficient taken as:

$$C_a = 1.0 - 0.2(\frac{R_a}{1400})^2$$

b_1, b_2 : Height of shell element in way of bracket toe in cargo hold FE model, in mm.

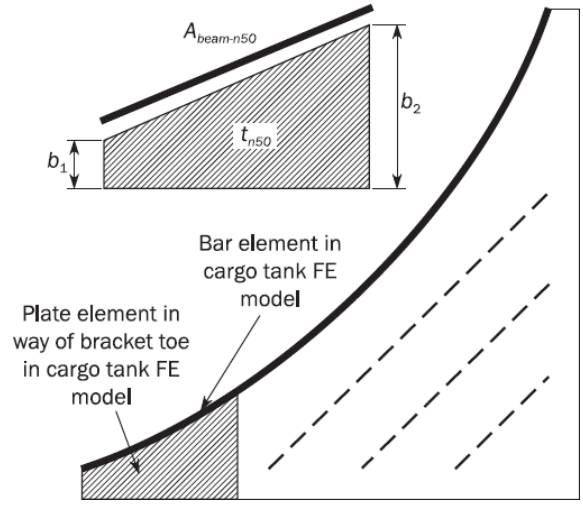
$A_{beam-n50}$: Sectional area of beam or rod element in cargo hold FE model representing the face plate of bracket, in mm^2.

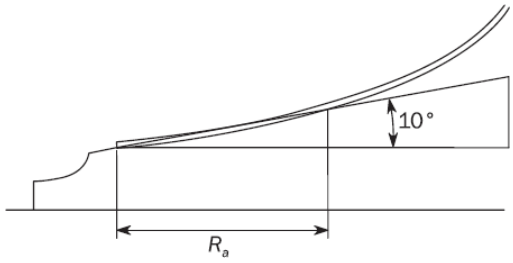
σ_{beam} : Beam or rod element axial stress determined from cargo hold FE analysis, in N/mm^2.

σ_{vm} : Von Mises stress of shell element in way of bracket toe determined from cargo hold FE analysis, in N/mm^2.

t_{n50} : Net thickness of shell element in way of bracket toe, in mm.

R_a : Leg length, in mm, not to be taken as greater than 1400 mm.





3.3.2 Screening criteria

Stresses in areas defined in [3.1], calculated for all applicable FE load combinations given in [5], are to be checked against the following screening criteria.

$\lambda_{sc} \leq \lambda_{scperm}$

where:

λ_{sc} : Screening factor defined in [3.3.1]

λ_{scperm} : Permissible screening factor defined in [3.3.1]

Where the screening criteria are not met, fine mesh analysis of the corresponding structural detail is required and to be performed according to [1.1.3].

Screening factor for heels of transverse bulkhead horizontal stringers **Table 7**

λ_{sc} : Screening factor taken as:

- For heels at side horizontal girder and transverse bulkhead horizontal stringer, at the locations 1, 2 and 3 in figure below.

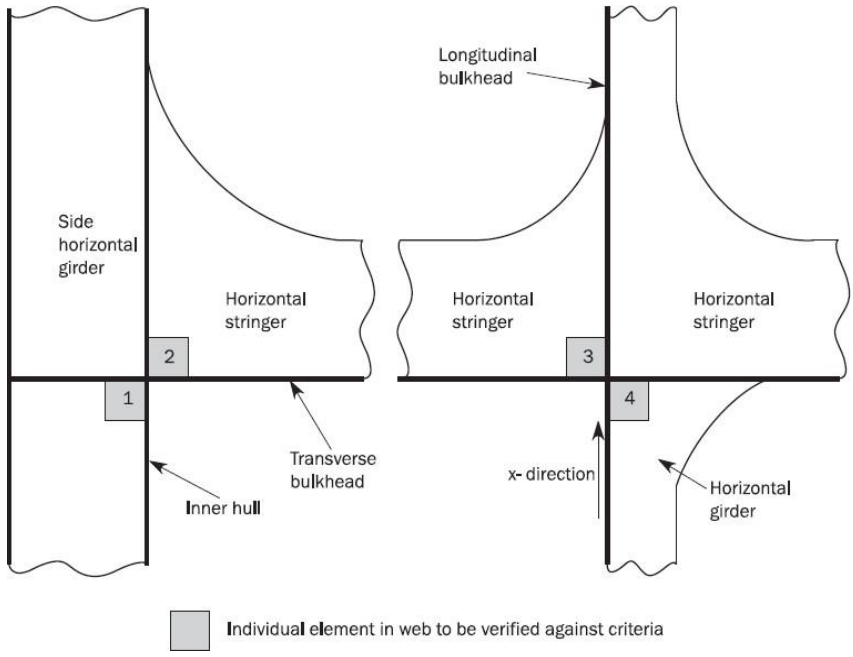
$$\lambda_{sc} = 1.67 \sigma_{vm} \frac{k}{235}$$

- For heel at longitu dinal bulkhead horizontal stringer, at the location 4 in figure below.

$$\lambda_{sc} = 3.2 |\sigma_x| \frac{k}{235}$$

σ_x : Axial stress in element x direction determined from cargo hold FE analysis in accordance with the coordinate system shown, in N/mm^2.

σ_{vm} : Von Mises stress of shell element in way of heel determined from cargo hold FE analysis, in N/mm^2.



	Individual element in web to be verified against criteria.

4 STRUCTURAL MODELLING

4.1 General

4.1.1

Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by fine mesh zones incorporated into the cargo hold model. Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo hold model may be used.

4.2 Extent of model

4.2.1

If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo hold model, such as web frame, girders, stringers and floors.

4.3 Mesh size

4.3.1

The mesh size in the fine mesh zones is not to be greater than 50 ×50 mm.

4.3.2

The extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained.

4.4 Elements

4.4.1

All plating within the fine mesh zone is to be represented by shell elements. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements within the fine mesh model are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angles of less than 45°or greater than 135°, are to be avoided. Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.

4.4.2
Where fine mesh analysis is required for main bracket end connections, including the end connection of hold frames of single skin bulk carriers, the fine mesh zone is to be extended at least 10 elements in all directions from the area subject to assessment, see Figure 9.

4.4.3
Where fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50 ×50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modelled with shell elements. Web stiffeners close to an opening may be modelled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Example of fine mesh zone around an opening is shown in Figure 10.

4.4.4
Face plates of openings, primary supporting members and associated brackets are to be modelled with at least two elements across their width on either side.

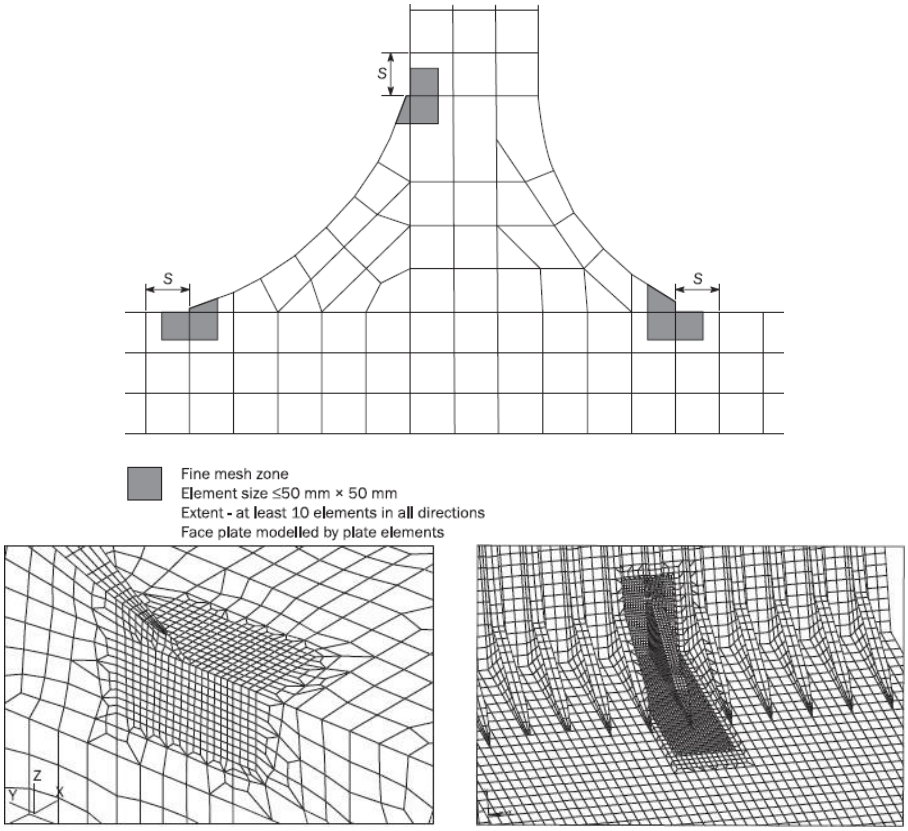


Figure 9 Fine mesh zone around bracket toes

4.5 Transverse web frames

4.5.1
In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of a typical transverse web frame.

4.5.2
Where a FE sub model is used, the model is to have an extent of at least 1+1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. For bulk carriers, the web frame space is the longer space of web frames in the upper wing and the lower hopper tanks. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model.

4.5.3

The full depth and full breadth of the ship are to be modelled, see Figure 11.

Figure 12 shows a close up view of the finite element mesh at the lower part of the vertical web and backing brackets.

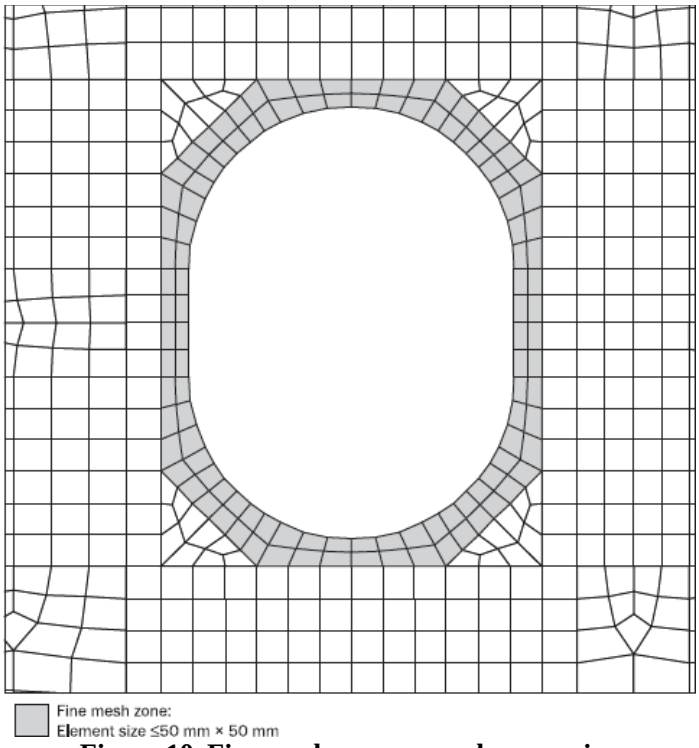


Figure 10 Fine mesh zone around an opening

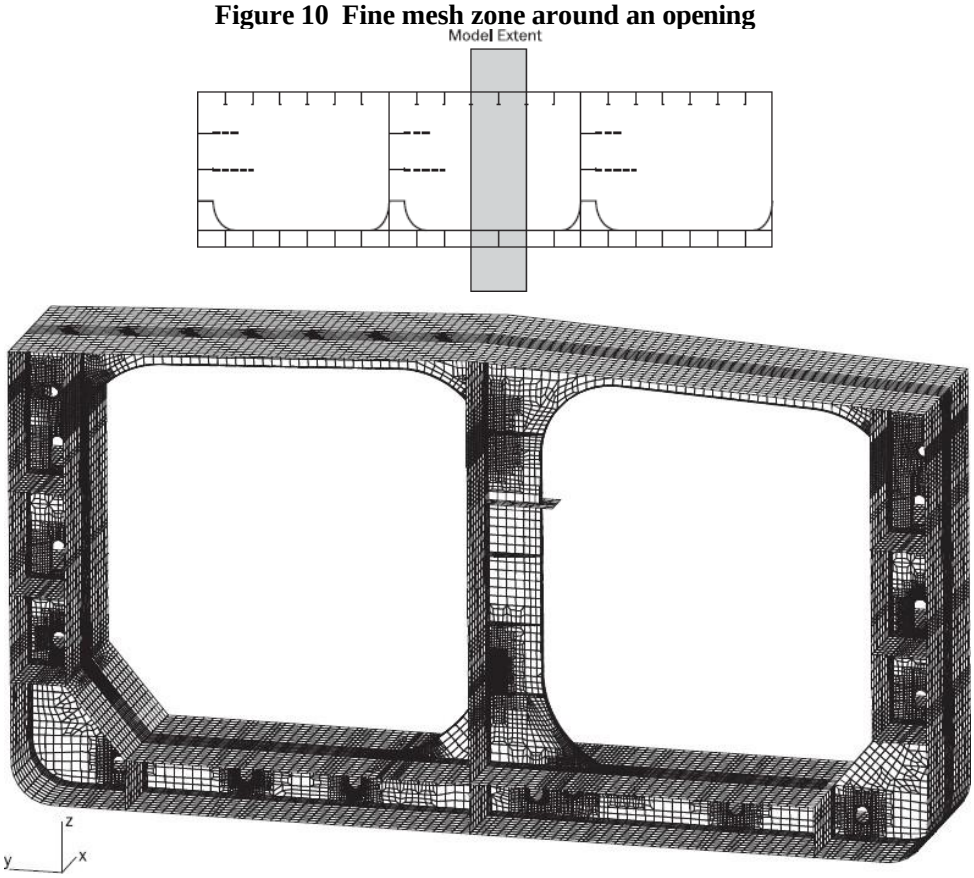


Figure 11 Example of extent of local model for fine mesh analysis of web frame bracket connections and openings

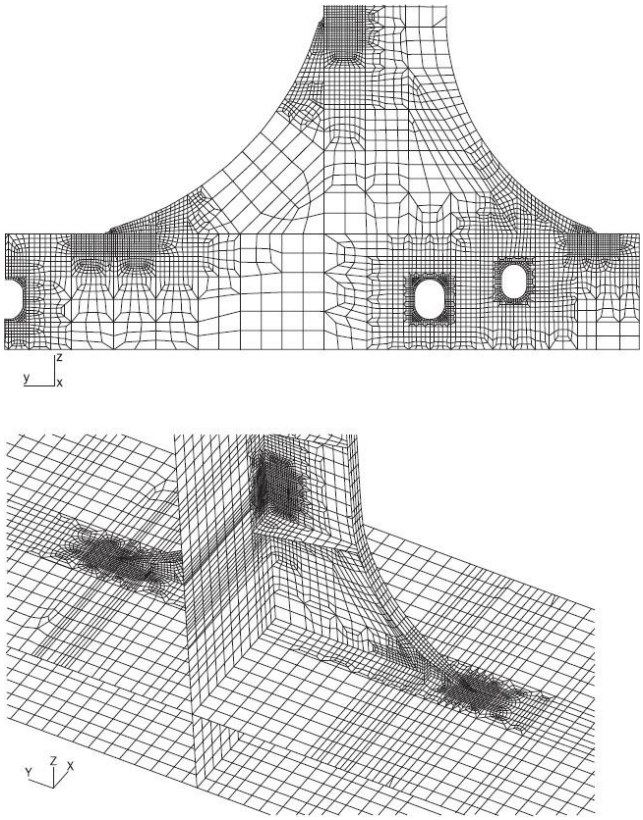


Figure 12 Close-up view of finite element mesh at the lower part of a transverse web frame

4.6 Transverse bulkhead stringers, buttress and adjacent web frame

4.6.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of transverse bulkhead structures and adjacent web frame.

4.6.2

Due to the structural interaction among the transverse bulkhead, horizontal stringers, web frames, deck and double bottom, it is recommended that the FE local model represents a full section of the hull. Longitudinally, the ends of the model should be extended at least one web frame space beyond the areas that require investigation, see Figure 13.

4.6.3

Alternatively, it is acceptable to use a number of local models, as shown in Figure 14, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship are to be modelled. For the analysis of buttress structure, the local model width should be at least 4+4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

4.6.4

Figure 15 shows the finite element mesh on a transverse bulkhead horizontal stringer. Figure 16 shows the local model for the analysis of buttress connections to transverse bulkhead and double bottom structure, and openings.

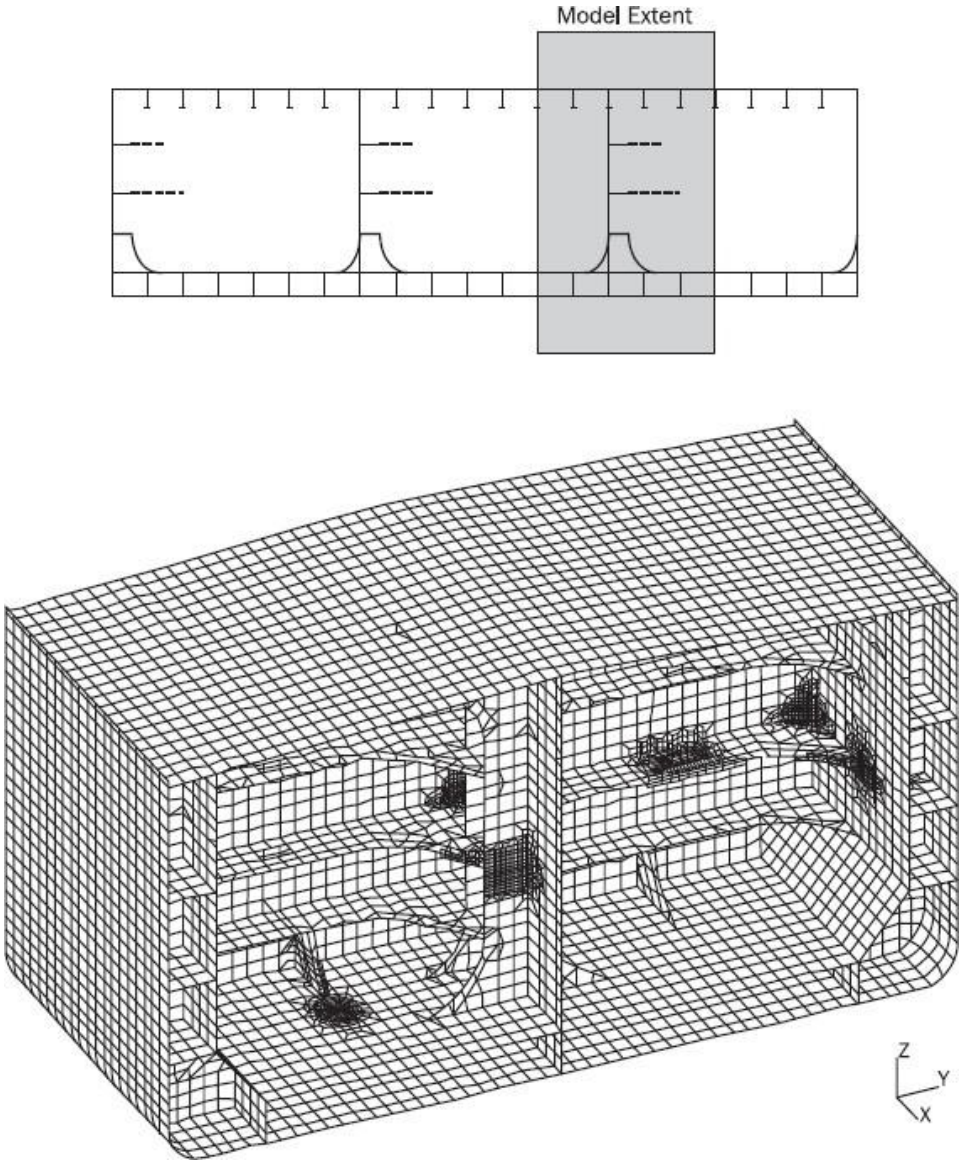


Figure 13 Example of local model for fine mesh analysis of transverse bulkhead and adjacent structure

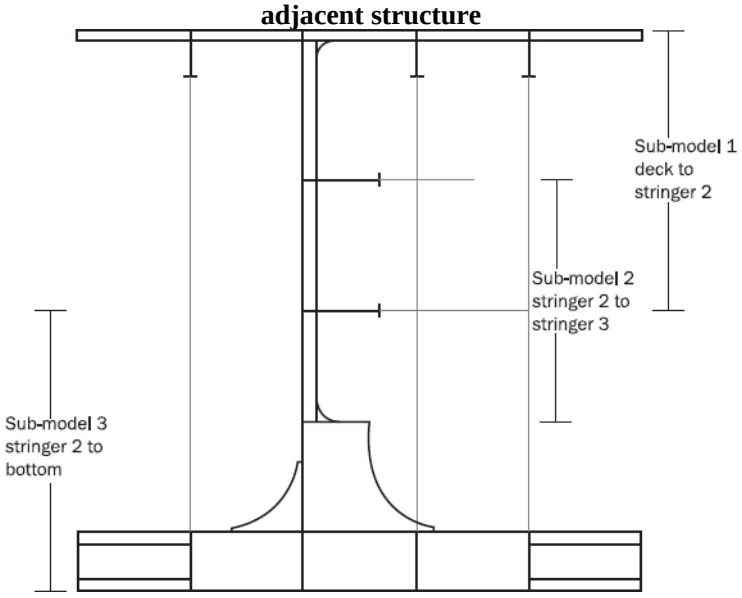


Figure 14 Example of local analysis of transverse bulkhead structure using local models

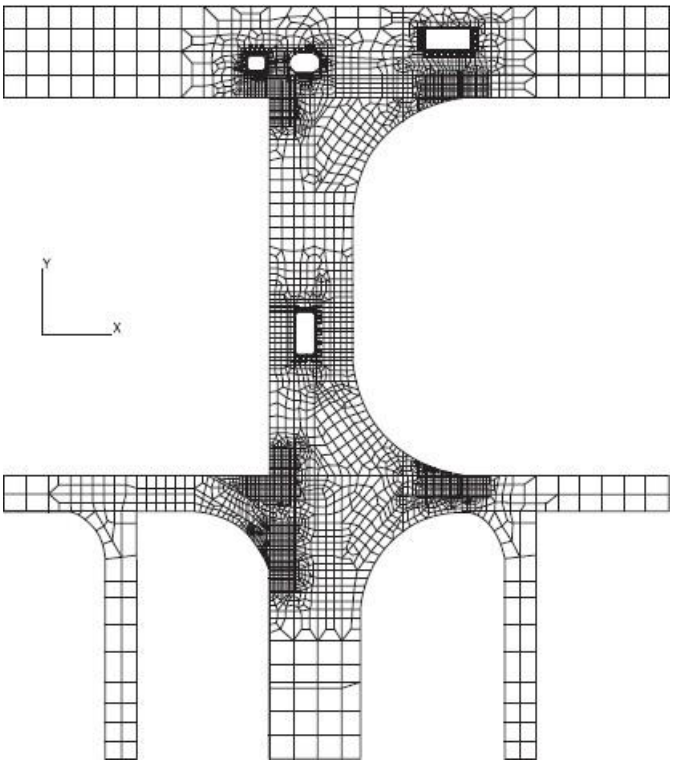


Figure 15 Example of finite element mesh on transverse bulkhead horizontal stringer

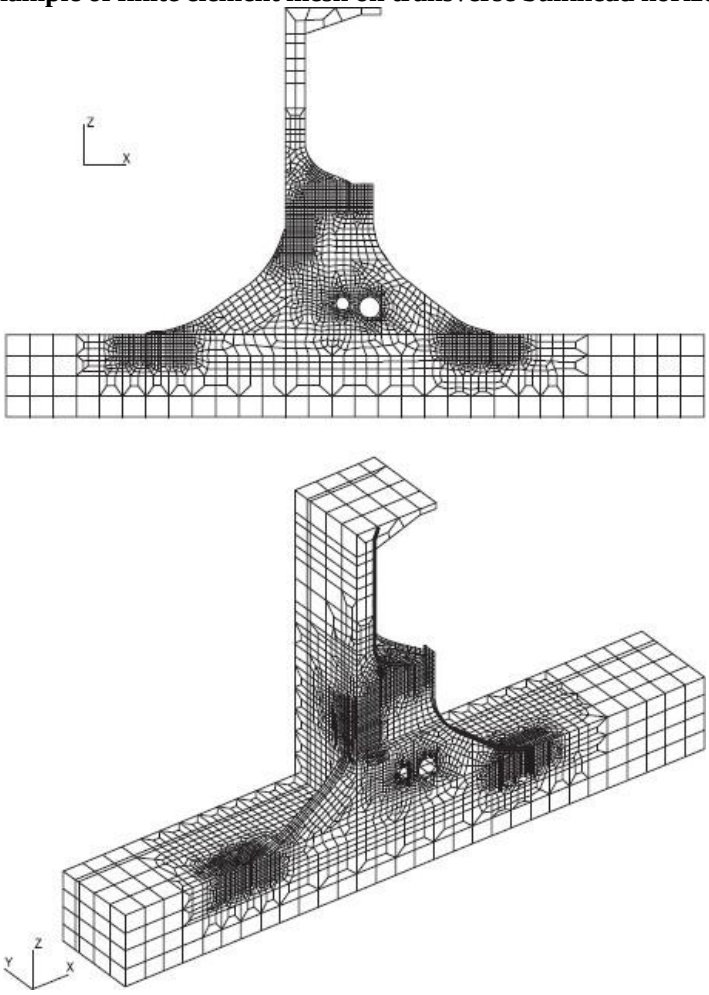


Figure 16 Example of local model for the analysis of buttress connections to bulkhead and double bottom structure, showing port half of model

4.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

4.7.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners.

4.7.2

Where a local FE model is used, each end of the model is to be extended longitudinally at least two web frame spaces from the areas under investigation. The model width is to be at least 2+2 longitudinal spaces. Figure 17 shows the longitudinal extent of the local model for the analysis of deck and double bottom longitudinal stiffeners and adjoining transverse bulkhead vertical stiffener.

4.7.3

The web of the longitudinal stiffeners outside of the fine mesh zone should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The flange of the longitudinal stiffeners and face plate of brackets should be modelled with at least two shell elements across its width at one side.

4.7.4

The mesh size and extent of the fine mesh zone is to be in accordance with [4.3.1], see also Figure 17.

4.8 Corrugated bulkheads

4.8.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of connections of corrugated bulkheads to lower stool and the connection between lower stool and inner bottom.

4.8.2

The minimum extents of the local model are as follows, see also Figure 18:

a) Vertically, the model is to be extended from the bottom of the ship to a level at least 2 m above the corrugation and lower stool connection. The upper boundary of the local model is to coincide with the horizontal mesh line of the cargo hold FE model for the purpose of applying boundary displacements, see [4.2].

b) For transverse corrugated bulkheads, the local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the local model covers two lower stool transverse web/diaphragm spaces). The end diaphragms need not be modelled.

c) For the longitudinal corrugated bulkheads, the local model is to be extended to the nearest web frame on each side of the fine mesh zone (i.e. the local model covers two frame spaces). The end web frames need not be modelled.

d) For the corrugation and lower stool connection located close to the intersection of transverse and longitudinal corrugated bulkheads, such as for product tanker, the local model is to cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever is relevant. In addition the local model is to be extended at least one diaphragm/web frame outside the intersection between the transverse stool and the longitudinal stool.

e) For lower stool to inner bottom connection, the connection between inner bottom, lower stool plate, diaphragm and double bottom girder, where applicable, is the centre of the fine mesh zone.

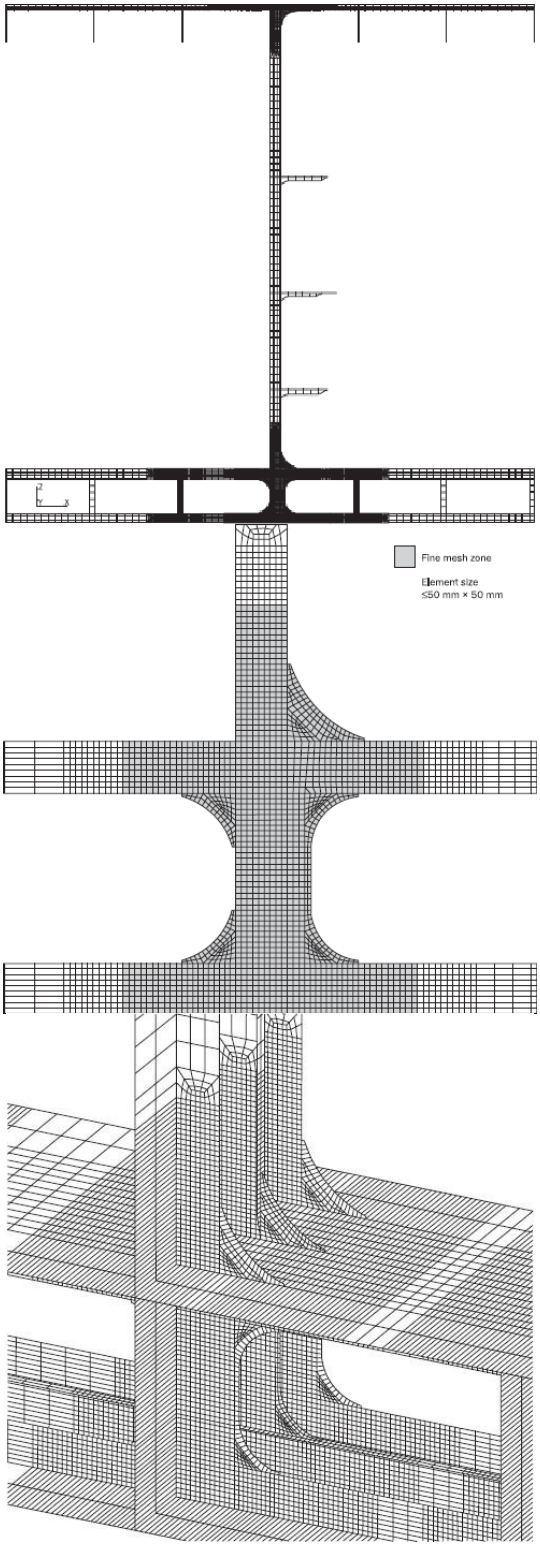


Figure 17 Example of local model for fine mesh analysis of end connections and web stiffeners of deck and double bottom longitudinals

4.8.3

For corrugation connection, the fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and a further extension of 500 mm from each end of the corrugation web, i.e. the fine mesh zone covers at least four corrugation knuckles, see Figure 18 and Figure 19. The mesh size within the fine mesh zone is not to be greater than 50 ×50 mm.

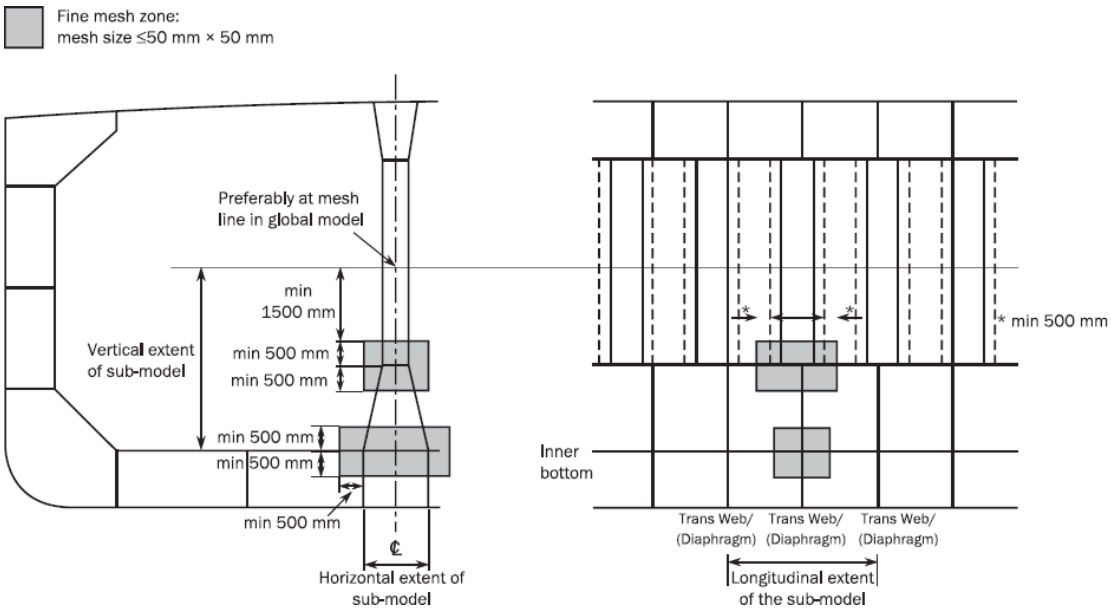


Figure 18 Extent of local model and fine mesh zone for the analysis of corrugated bulkhead connection to lower stool and inner bottom

Above figures show extent of local model and fine mesh zone on longitudinal corrugated bulkhead connection to lower stool. Similar extent applies to transverse corrugated bulkhead.
The model extents shown above are the minimum extents.

4.8.4

Diaphragm webs, brackets inside the lower stool and all stiffeners on the stool plate and diaphragm are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragm, web and flange of vertically orientated stiffeners, and brackets in the fine mesh zone.

4.8.5

Horizontally orientated stiffeners within the fine mesh zone are to be represented by either shell or beam elements.

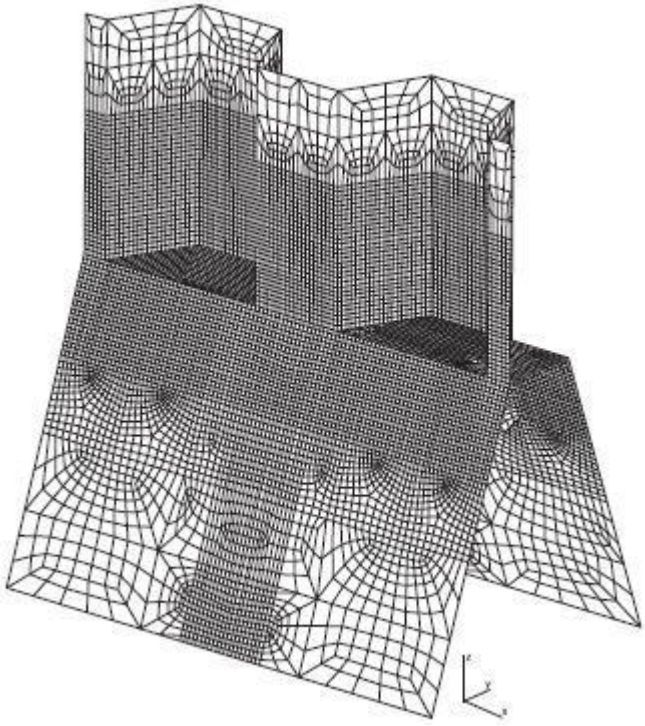


Figure 19 Example of partial local model for the analysis of connection of corrugated bulkhead to lower stool

4.8.6
Figure 19 shows the details of finite element local model for the fine mesh analysis of longitudinal bulkhead to lower stool connection.

4.8.7
Figure 20 shows the details finite element local model for the fine mesh analysis of lower stool to inner bottom connection.

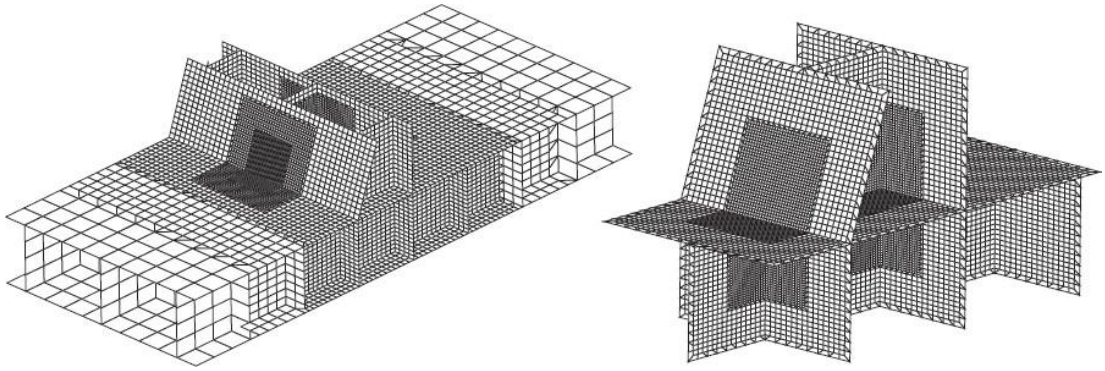


Figure 20 Example of partial local model for the analysis of connection of lower stool to inner bottom

4.9 Hatch corner structures
4.9.1
In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of hatch corner structures.

4.9.2
The high stress areas, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection, need to be analysed by fine mesh model. The fine mesh zones should cover these areas, see Figure 21.

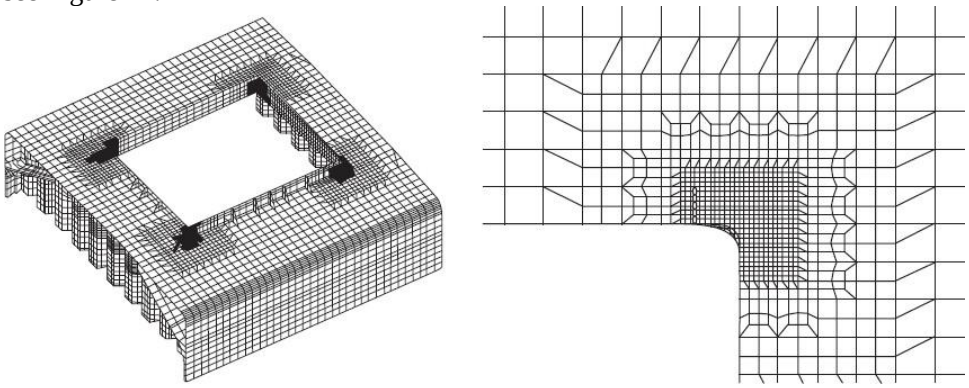


Figure 21 Example of local model for the analysis of hatch opening structures

5 FE LOAD COMBINATIONS
5.1 General
5.1.1
The fine mesh detailed stress analysis is to be carried out for all FE load combinations applied to the corresponding cargo hold analysis.
5.2 Application of loads and boundary conditions
5.2.1 General
Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.
Where there are nodes on the local model boundaries which are not coincident with the nodal

points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.
All local loads, including any loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model are to be applied to the model.

6 ANALYSIS CRITERIA

6.1 Stress assessment

6.1.1 General

Stress assessment of the fine mesh analysis is to be carried out for the FE load combinations specified in Ch4, Sec 8.

6.1.2 Reference stress

Reference stress is von Mises stress, σ_{vm}, which is to be calculated based on the membrane normal and shear stresses of the shell element evaluated at the element centroid. The stresses are to be evaluated at the mid plane of the element.

6.1.3 Permissible stress

The maximum permissible stresses are based on the mesh size of 50 ×50 mm as specified in [4.1] to [4.4]. Where a smaller mesh size is used, an area weighted von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area. The average stress is to be calculated based on stresses at element centroid; stress values obtained by interpolation and/or extrapolation are not to be used. Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2 Acceptance criteria

6.2.1

Verification of stress results against the acceptance criteria is to be carried out in accordance with [6.1]. The structural assessment is to demonstrate that the stress complies with the following criteria:

$\lambda_f \leqslant \lambda_{fperm}$

where:

λ_f : Fine mesh yield utilisation factor.

$$\lambda_f = \frac{\sigma_{vm}}{R_Y} \quad \text{for shell elements in general}$$

$$\lambda_f = \frac{|\sigma_{axial}|}{R_Y} \quad \text{for rod or beam elements in general}$$

σ_{vm} : Von Mises stress, in N/mm^2.

σ_{axial} : Axial stress in rod element, in N/mm^2.

λ_{fperm} : Permissible fine mesh utilisation factor, taken as:

- Element not adjacent to weld:
  - λ_{fperm} = 1.70 f_f for S+D
  - λ_{fperm} = 1.36 f_f for S
- Element adjacent to weld:
  - λ_{fperm} = 1.50 f_f for S+D
  - λ_{fperm} = 1.20 f_f for S

f_f : Fatigue factor, taken as:

- f_f = 1.0 in general, including the free edge of base material,
- f_f =1.2 for details assessed by very fine mesh analysis complying with the fatigue assessment criteria. given in Ch 9, Sec 2.

Note 1: The maximum permissible stresses are based on the mesh size of 50 ×50 mm. Where a smaller mesh size is used, an average von Mises stress calculated in accordance with [6.1] over an area equal to the specified mesh size may be used to compare with the permissible stresses.

Note 2: Average von Mises stress is to be calculated based on weighted average against element areas:

$$\sigma_{vm-av} = \frac{\sum_1^n A_i \sigma_{vm-i}}{\sum_1^n A_i}$$

where:

σ_{vm-av} is the average von Mises stress.

Note 3: Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2.2 Lower stool not fitted to a transverse or longitudinal corrugated bulkhead

Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the permissible stresses given in [6.2.1] are to be reduced by 10% for the areas under investigation by fine mesh analysis.

Chapter 8 BUCKLING

Section 1 GENERAL

1 INTRODUCTION

1.1 Assumption

1.1.1

This chapter contains the strength criteria for buckling and ultimate strength of local supporting members, primary supporting members and other structures such as pillars, corrugated bulkheads and brackets. These criteria are to be applied as specified in Ch 6 for hull local scantlings and in Ch 7 for direct strength analysis.

1.1.2

For each structural member, the characteristic buckling strength is to be taken as the most unfavourable /critical buckling failure mode.

1.1.3

Unless otherwise specified, the scantling requirements of structural members in this chapter are based on net scantling obtained by removing *tc* from the gross offered thickness, where *tc* is defined in Ch 3, Sec 3.

1.1.4

In this chapter, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

2 APPLICATION

2.1 Scope

2.1.1

The buckling checks are to be performed according to:

- Ch 8, Sec 2 for the slenderness requirements of plates, longitudinal and transverse stiffeners, primary supporting members and brackets.
- Ch 8, Sec 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures.
- Ch 8, Sec 4 for the buckling requirements of the FE analysis for the plates, stiffened panels and other structures.
- Ch 8, Sec 5 for the buckling capacity of prescriptive and FE buckling requirements.

2.1.2 Stiffener

The buckling check of the stiffeners referred to in this Chapter is applicable to the stiffener fitted along the long edge of the buckling panel.

2.1.3 Enlarged stiffener

Enlarged stiffeners, used for Permanent Means of Access (PMA), whose net web height are above 700 mm, and net offered section modulus are 3 times greater than the smaller one of adjacent surrounding stiffeners not used for PMA, are to comply with the following requirements:

a) Slenderness requirements for primary supporting members as follows:
   - For enlarged stiffener web, see item (a) of Ch 8, Sec 2, [4.1.1].
   - For enlarged stiffener flange, see item (b) of Ch 8, Sec 2, [4.1.1] and Ch 8, Sec 2, [5.1].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 2, [3.1.1] and Ch 8, Sec 2, [3.1.3].

b) Buckling strength of prescriptive requirements as follows:
   - For enlarged stiffener web, see Ch 8, Sec 3, [3.2].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

c) All structural elements used for PMA are to be complied with for the buckling requirements of the FE analysis in Ch 8, Sec 4 when applicable.

d) Buckling strength of longitudinal PMA platforms without stiffeners fitted on enlarged stiffener web is to be checked using the criteria for local supporting members in Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

3 DEFINITIONS

3.1 General

3.1.1 Buckling definition

'Buckling' is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear and lateral load. The buckling strength or capacity can take into account the internal redistribution of loads depending on the load situation, slenderness and type of structure.

3.1.2 Buckling capacity

Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set.

Buckling capacity assessment utilises the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures, the capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilisation levels.

3.1.3 Assessment methods

The buckling assessment is carried out according to one of the two methods taking into account different boundary condition types:

- Method A: All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.
- Method B: The edges of the elementary plate panel are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

3.2 Buckling utilisation factor

3.2.1

The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

3.2.2

For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the equivalent applied stress and the corresponding buckling capacity, as shown in Figure 1, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_u} = \frac{1}{\gamma_c}$$

where:

W_{act} : Equivalent applied stress, in N/mm^2, the actual applied stress are given in Sec 3 and Sec 4 respectively for buckling assessment by prescriptive and direct strength analysis.

W_u : Equivalent buckling capacity, in N/mm^2, for plates and stiffeners, their respective buckling or ultimate capacities are given in Sec 5.

γ_c : Stress multiplier factor at failure.

For each typical failure mode, the corresponding capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse.

Figure 1 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

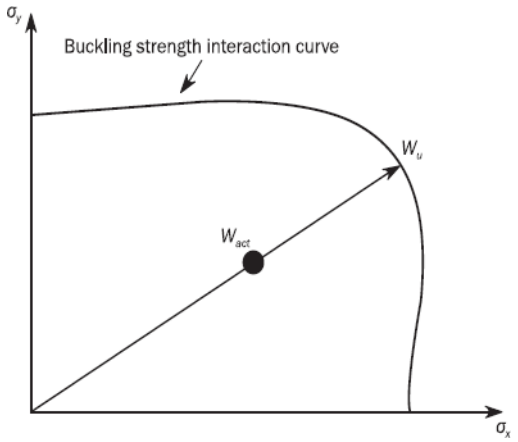


Figure 1 Example of buckling capacity and buckling utilisation factor

3.3 Allowable buckling utilisation factor

3.3.1 General structural elements

The allowable buckling utilisation factor is defined in Table 1.

Allowable buckling utilisation factor **Table 1**

Structural component	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Stiffened and unstiffened panels Vertically stiffened side shell plating of single side skin bulk carrier Web plate in ways of openings	1.00 for load combination: S+D 0.80 for load combination: S
Struts, pillars and cross ties	0.75 for load combination: S+D 0.65 for load combination: S
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool.	0.90 for load combination: S+D 0.72 for load combination: S
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only.	0.81 for load combination: S+D 0.65 for load combination: S
Note1: Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. Note2: Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.	

3.4 Buckling acceptance criteria

3.4.1

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$\eta_{act} \leqslant \eta_{all}$

where:

η_{act} :Buckling utilisation factor based on the applied stress, defined in [3.2.2].

η_{all} :Allowable buckling utilisation factor as defined in [3.3].

Section 2 SLENDERNESS REQUIREMENTS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

$b_{f\text{-}out}$: Maximum distance, in mm, from mid thickness of the web to the flange edge, as shown in Figure 1.

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

l_b : Effective length of edge of bracket, in mm, as defined in Table 3.

s_{eff} : Effective width of attached plate of stiffener, in mm, taken equal to:

$s_{eff} = 0.8\ s$

t_f : Net flange thickness, in mm.

t_p : Net thickness of plate, in mm.

t_w : Net web thickness, in mm.

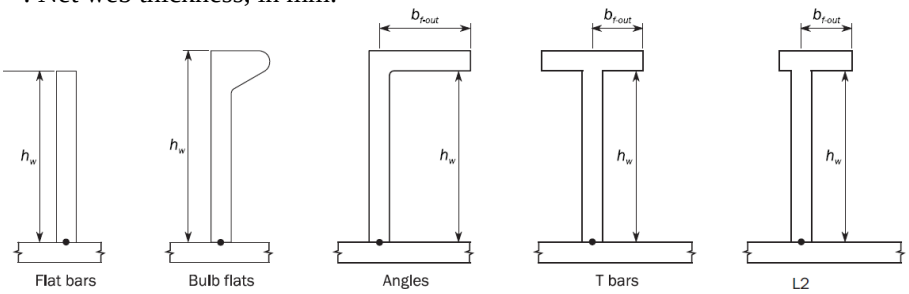


Figure 1 Stiffener scantling parameters

1 STRUCTURAL ELEMENTS

1.1 General

1.1.1

All structural elements are to comply with the applicable slenderness and proportion requirements given in [2] to [6], except for the ones listed below:

- Bilge plates within the cylindrical part of the ship and radius gunwale;
- Corrugation;
- Structure members in superstructures and deck houses, if the structural members do not contribute to the longitudinal strength.

Pillars in superstructures and deckhouses are to comply with the applicable slenderness and proportion requirements given in [6.1].

2 PLATES

2.1 Net thickness of plate panels

2.1.1

The net thickness of plate panels is to satisfy the following criteria:

$$t_p \geq \frac{b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

C : Slenderness coefficient taken as:

$C = 100$ for hull envelope and cargo and tank boundaries.

$C = 125$ for other structures.

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.

A lower specified minimum yield stress may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4 are satisfied for the strake assumed in the same lower specified minimum yield stress value

3 STIFFENERS

3.1 Proportions of stiffeners

3.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:
C_w, C_f : Slenderness coefficients given in Table 1.

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-\max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

Slenderness coefficients **Table 1**

Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb bars	45	-
Flat bars	22	-

For built-up profile where the relevant yielding strength defined in Ch 6 and Ch 7 for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 in Ch 8, Sec 2, Table 1 and the edge stiffener can be assessed as a flat bar stiffener according to [3.1.1]. The requirement to flange in [3.1.2] shall still apply.

3.1.2 Net dimensions of angle , L2 and T-bars
The total flange breadth b_f in mm, for angle, L2 and T-bars is to satisfy the following criterion:
$b_f \geqslant 0.2h_w$

3.1.3 Bending stiffness of stiffeners
The net moment of inertia, in cm^4, of the stiffener with the effective width of attached plate, s_{eff} about the neutral axis parallel to the attached plating , is not to be less than the minimum value given by:

$$I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$$

where:
A_{eff} : Net sectional area of stiffener including effective attached plate, s_{eff}, in cm^2.
R_{eH} : Specified minimum yield stress of the material of the attached plate, in N/mm^2.
C : Slenderness coefficient taken as:
C = 1.43 for longitudinal stiffeners including sniped stiffeners.
C = 0.72 for other stiffeners.

4 PRIMARY SUPPORTING MEMBERS

4.1 Proportions and stiffness

4.1.1 Proportions of web plate and flange

The net thicknesses of the web plates and flanges of primary supporting members are to satisfy the following criteria:

a) Web plate:

$$t_w \geq \frac{s_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

s_w : Plate breadth, in mm, taken as the spacing of the web stiffeners.

C_w : Slenderness coefficient for the web plate taken as:
$C_w = 100$

C_f : Slenderness coefficient for the flange taken as:
$C_f = 12$

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.
For the web plates, a lower R_{eH} may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4, if applicable, are satisfied for the structure assumed in the same lower R_{eH}.

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-\max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

4.1.2 Deck transverse primary supporting members

The net moment of inertia for deck transverse primary supporting members, $I_{psm\text{-}n50}$, in cm^4, supporting deck longitudinals subject to axial compressive hull girder stress, is to comply, within its central half of the bending span, with the following criterion:

$$I_{psm-n50} \geq 300\frac{l_{bdg}^4}{S^4 s} I_{st}$$

where:

$I_{psm\text{-}n50}$: Net moment of inertia, in cm^4, of deck transverse primary supporting member, with effective width of attached plate equal to 0.8S.

l_{bdg} : Effective bending span of deck transverse primary supporting member, in m, as defined in Ch 3, Sec 7.

S : Spacing of deck transverse primary supporting members, in m, as defined in Ch 3, Sec 7.

I_{st} : Moment of inertia of deck stiffeners within the central half of the bending span, in cm4, as given in[3.1.3].

4.2 Web stiffeners of primary supporting members

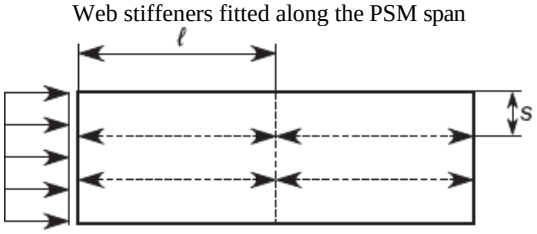
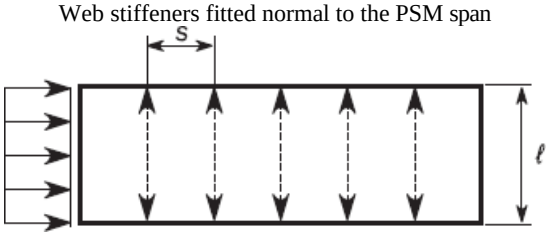
4.2.1 Proportions of web stiffeners

The net thickness of web and flange of web stiffeners fitted on primary supporting members is to satisfy the requirements specified in [3.1.1] and [3.1.2].

4.2.2 Bending stiffness of web stiffeners

The net moment of inertia, in cm^4, of web stiffener, I_{st}, fitted on primary supporting members, with effective attached plate, s_{eff}, is not to be less than the minimum moment of inertia defined in Table 2.

Stiffness criteria for web stiffeners **Table 2**

	Stiffener arrangement	Minimum moment of inertia of web stiffeners, in cm^4
A	Web stiffeners fitted along the PSM span 	$I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$
B	Web stiffeners fitted normal to the PSM span 	$I_{st} \geq 1.14 ls^2 t_w \left(2.5\frac{1000l}{s} - 2\frac{s}{1000l}\right)\frac{R_{eH}}{235}\cdot 10^{-5}$

where:

C : Slenderness coefficient to be taken as:

C = 1.43 for longitudinal stiffeners including sniped stiffeners.

C = 0.72 for other stiffeners.

L : Length of web stiffener, in m.

For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local support members.

For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary supporting member as shown for stiffener arrangement B.

A_{eff} : Net section area of web stiffener including effective attached plate, s_{eff}, in cm^2.

t_w : Net web thickness of the primary supporting member, in mm.

R_{eH} : Specified minimum yield stress of the material of the web plate of the primary supporting member, in N/mm^2.

5 BRACKETS

5.1 Tripping brackets

5.1.1 Unsupported flange length

The unsupported length of the flange of the primary supporting member, in m, i.e. the distance between tripping brackets, is not to be greater than:

$$s_b = b_f C \sqrt{\frac{A_{f-n50}}{\left(A_{f-n50} + \frac{A_{w-n50}}{3}\right)}\left(\frac{235}{R_{eH}}\right)}$$, but need not be less than $S_{b\text{-}min}$

where:

b_f : Flange breadth of primary supporting members, in mm.

C : Slenderness coefficient taken as:

C = 0.022 for symmetrical flanges.

C = 0.033 for asymmetrical flanges.

$A_{f\text{-}n50}$: Net cross sectional area of flange, in cm^2.

$A_{w\text{-}n50}$: Net cross sectional area of the web plate, in cm^2.

R_{eH} : Specified minimum yield stress of the PSM material, in N/mm^2.

$S_{b\text{-}min}$: Minimum unsupported flange length taken as:

$S_{b\text{-}min}$= 3.0 m for tank/hold boundaries or hull envelope including external decks.

$S_{b\text{-}min}$= 4.0 m for other areas.

5.1.2 Edge stiffening

Tripping brackets on primary supporting members are to be stiffened by a flange or edge stiffener if the effective length of the edge, l_b as defined in Table 3, in mm, is greater than:

$l_b = 75t_b$

where:

t_b : Bracket net web thickness, in mm.

5.2 End brackets

5.2.1 Proportions

The net web thickness of end brackets, in mm, subject to compressive stresses is not to be less than:

$$t_b = \frac{d_b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

d_b : Depth of brackets, in mm, as defined in Table 3.

C : Slenderness coefficient as defined in Table 3.

R_{eH} : Specified minimum yield stress of the end bracket material, in N/mm^2.

5.3 Edge reinforcement

5.3.1 Edge reinforcements of bracket edges

The depth of stiffener web, h_w in mm, of edge stiffeners in way of bracket edges is not to be less than:

$$h_w = Cl_b / 1000\sqrt{\frac{R_{eH}}{235}}$$ or 50 mm, whichever is greater.

where:

C : Slenderness coefficient taken as:

C = 75 for end brackets.

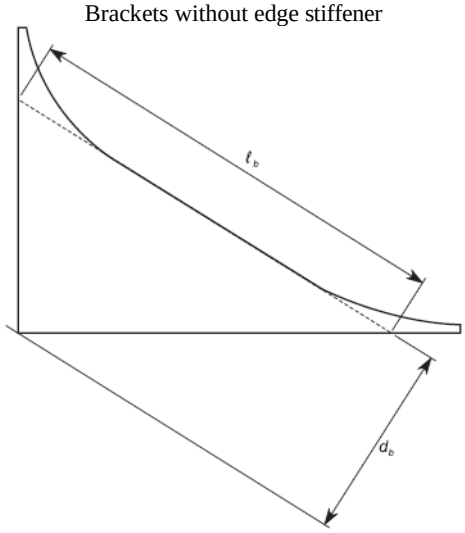
C = 50 for tripping brackets.

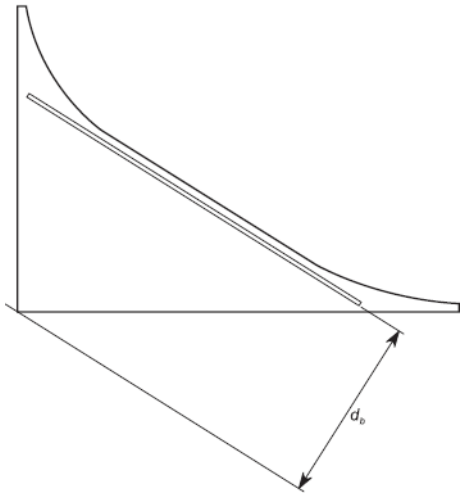
R_{eH} : Specified minimum yield stress of the stiffener material, in N/mm$_2$.

5.3.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in[3.1.1] and [3.1.2].

Buckling coefficient, *C*, for proportions of brackets **Table 3**

Mode	*C*
Brackets without edge stiffener 	$C = 20\left(\frac{d_b}{l_b}\right) + 16$ where: $0.25 \le \frac{d_b}{l_b} \le 1.0$

Mode	*C*
Brackets with edge stiffener 	$C = 70$

6 OTHER STRUCTURES

6.1 Pillars

6.1.1 Proportions of I-section pillars

For I-sections, the thickness of the web plate and the flange thickness are to comply with requirements specified in [3.1.1] and [3.1.2].

6.1.2 Proportions of box section pillars

The thickness of thin walled box sections is to comply with the requirements specified in item (a) of [3.1.1].

6.1.3 Proportions of circular section pillars

The net thickness, *t*, of circular section pillars, in mm, is to comply with the following criterion:

$$t \geq \frac{r}{50}$$

where:

r : Mid thickness radius of the circular section, in mm.

6.2 Edge reinforcement in way of openings

6.2.1 Depth of edge stiffener

When fitted as shown in Figure 2, the depth of web, h_w in mm, of edge stiffeners in way of openings is not to be less than:

$$h_w = Cl\sqrt{\frac{R_{eH}}{235}}$$ or 50 mm, whichever is greater.

where:

C : Slenderness coefficient taken as:

$C = 50$

R_{eH} : Specified minimum yield stress of the edge stiffener material, in N/mm^2.

l : Length of edge stiffener in way of opening, in m, as defined in Figure 2.

6.2.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in[3.1.1] and [3.1.2].

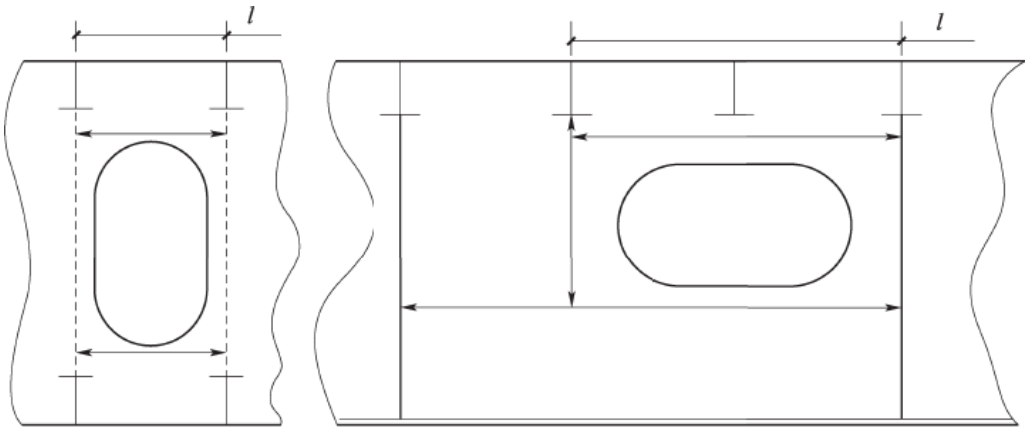


Figure 2 Typical edge reinforcements

Section 3 PRESCRIPTIVE BUCKLING REQUIREMENTS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].
EPP : Elementary Plate Panel as defined in Ch 3, Sec 7, [2.1].
LCP : Load calculation point as defined in Ch 3, Sec 7, [2.2.2] and Ch 3, Sec 7, [3.2].

1 GENERAL

1.1 Scope

1.1.1

This section applies to plate panels including curved plate panels and stiffeners subject to hull girder compression and shear stresses. In addition the following structural members subject to compressive stresses are to be checked:

- Corrugation of longitudinal corrugated bulkhead.
- Strut.
- Pillar.
- Cross tie.

1.1.2

The hull girder buckling strength requirements apply along the full length of the ship.

1.1.3 Design load sets

The buckling checks are to be performed for all design load sets defined in Ch 6, Sec 2, [2], both in intact and in flooded conditions with pressure combination defined in Ch 6, Sec 2, [1.3].
For each design load set, for all dynamic load cases, the lateral pressure is to be determined according to Ch 4 at the load calculation point defined in Ch 3, Sec 7, and is to be applied together with the hull girder stress combinations given in [2.2].

1.2 Equivalent plate panel

1.2.1

In longitudinal stiffening arrangement, when the plate thickness varies over the width b, of a plate panel, the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where:

l_1: Width of the part of the net plate panel with the smaller net plate thickness, t_1, in mm, as defined in Figure 1.

l_2: Width of the part of the net plate panel with the greater net plate thickness, t_2, in mm, as defined in Figure 1.

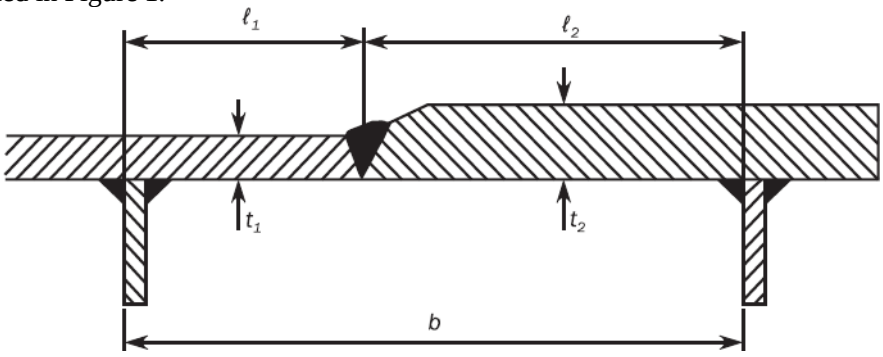


Figure 1 Plate thickness change over the width

1.2.2

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

1.2.3 Materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

2 HULL GIRDER STRESS

2.1 General

2.1.1

The hull girder bending stresses, σ_{hg}, in N/mm^2, are determined according to Ch 6, Sec 2.

2.1.2

The hull girder shear stresses, τ_{hg}, in N/mm^2, in the plate *i* are determined as follows:

$$\tau_{hg} = \frac{Q_{Tot}(x) q_{vi}}{t_{i-n50}} 10^3$$

where:

$Q_{Tot}(x)$: Total vertical shear force, in kN, at the ship longitudinal location *x*, taken as follows:

- For the design load combination S+D
  - For seagoing operations:
    $$Q_{Tot}(x) = \left| Q_{sw} + Q_{wv-LC} \right|$$
  - For flooded conditions at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above:
    $$Q_{Tot}(x) = \left| Q_{sw-f} + Q_{wv-LC} \right|$$
- For the design load combination S
  - For harbour/sheltered water operations:
    $$Q_{Tot}(x) = \left| Q_{sw-p} \right|$$

q_{vi} : Contribution ratio in way of the plate *i*, as defined in Ch 5, Sec 1, [3.2.1].

$t_{i\text{-}n50}$: Net thickness of the plate *i*, in mm as defined in Ch 5, Sec 1, [3.2.1], used for shear stress calculation.

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible positive or negative still water shear force in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

$Q_{wv\text{-}LC}$: Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered for the considered dynamic load case, defined in Ch 4, Sec 4, [3.5.3].

2.2 Stress combinations

2.2.1

Each elementary plate panel and stiffeners are to satisfy the criteria defined in [3] with the following stress combinations:

a) Longitudinal stiffening arrangement:
   - Stress combination 1 with:
     $\sigma_x = \sigma_{hg}$
     $\sigma_y = 0$
     $\tau = 0.7\tau_{hg}$
   - Stress combination 2 with:
     $\sigma_x = 0.7\sigma_{hg}$
     $\sigma_y = 0$

$\tau = \tau_{hg}$

b) Transverse stiffening arrangement:

- Stress combination 1 with:
  $\sigma_x = 0$
  $\sigma_y = \sigma_{hg}$
  $\tau = 0.7\tau_{hg}$
- Stress combination 2 with:
  $\sigma_x = 0$
  $\sigma_y = 0.7\sigma_{hg}$
  $\tau = \tau_{hg}$

where:

σ_{hg} : Hull girder bending stress in the elementary plate panel or stiffener, as defined in [2.1.1], in N/mm^2.

τ_{hg} : Hull girder shear stress, in N/mm^2, in the elementary plate panel or stiffener attached plate as defined in [2.1.2].

3 BUCKLING CRITERIA

3.1 Overall stiffened panel

3.1.1

The buckling strength of overall stiffened panels is to satisfy the following criterion:

$\eta_{Overall} \leqslant \eta_{all}$

where:

$\eta_{Overall}$: Maximum utilisation factor as defined in Ch 8, Sec 5, [2.1].

3.2 Plates

3.2.1

The buckling strength of elementary plate panels is to satisfy the following criterion:

$\eta_{Plate} \leqslant \eta_{all}$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to SP-A, as defined in Ch 8, Sec 5, [2.2].

For the determination of η_{Plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Ch 8, Sec 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\Psi_y = 1$.

3.3 Stiffeners

3.3.1

The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leqslant \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

Note 1: This capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in [3.1.1], is satisfied.

3.4 Vertically corrugated longitudinal bulkheads

3.4.1

The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$\eta_{Shear} \leqslant \eta_{all}$

where:

η_{Shear} : Maximum shear corrugated bulkhead utilisation factor.

$$\eta_{Shear} = \frac{\tau_{bhd}}{\tau_c}$$

τ_{bhd} : Hull girder shear stress, in N/mm^2, in the longitudinal bulkhead as defined in [2.1.2].
τ_c: Shear critical stress, in N/mm^2, as defined in Ch 8, Sec 5, [2.2.3].

3.5 Horizontally corrugated longitudinal bulkhead

3.5.1

Each corrugation, within the extension of half flange, web and half flange, is to satisfy the following criterion:

$\eta \leqslant \eta_{all}$

where:

η : Overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1].

3.6 Struts, pillars and cross ties

3.6.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta \leqslant \eta_{all}$

where:

η : Maximum buckling utilisation factor of struts, pillars or cross ties, defined in Ch 8, Sec 5, [3.1].

Section 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].

α : Aspect ratio of the plate panel, defined in Ch 8, Sec 5.

1 GENERAL

1.1 Scope

1.1.1

The requirements of this Section apply for the buckling assessment of direct strength analysis subjected to compressive stress, shear stress and lateral pressure.

1.1.2

All structural elements in the FE analysis carried out according to Ch 7 are to be assessed individually. The buckling checks have to be performed for the following structural elements:

- Stiffened and unstiffened panels, inclusive curved panels.
- Web plate in way of openings.
- Corrugated bulkhead.
- Vertically stiffened side shell of single side skin bulk carrier.
- Struts, pillars and cross ties.

2 STIFFENED AND UNSTIFFENED PANELS

2.1 General

2.1.1

The plate panel of hull structure is to be modelled as stiffened or unstiffened panel. Method A and Method B as defined in Ch 8, Sec 1, [3] are to be used according to Table 1 and Figure 1 to Figure 9.

2.1.2 Average thickness of plate panel

Where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled according to Ch 7 with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_{1}^{n} A_i t_i}{\sum_{1}^{n} A_i}$$

where:

Ai : Area of the *i*-th plate element.

ti : Net thickness of the *i*-th plate element.

n : Number of finite elements defining the buckling plate panel.

Structural members **Table 1**

Structural elements	Assessment method	Normal panel definition
Longitudinal structure, see Figure 1, Figure 5 and Figure 7		
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank side Longitudinal bulkheads	SP-A	Length: between web frames Width: between primary supporting members
Double bottom longitudinal girders in line with longitudinal bulkhead or connected to hopper tank side	SP-A	Length: between web frames Width: full web depth

Structural elements	Assessment method	Normal panel definition
Web of double bottom longitudinal girders not in line with longitudinal bulkhead or not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of horizontal girders in double side space connected to hopper tank side	SP-A	Length: between web frames Width: full web depth
Web of horizontal girders in double side space not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of single skin longitudinal girders or stringers	UP-B	Plate between local stiffeners/face plate/PSM
Transverse structure, see Figure 2, Figure 6 and Figure 8		
Web of transverse deck frames including brackets	UP-B	Plate between local stiffeners/face plate/PSM
Vertical web in double side space	SP-B	Length: full web depth Width: between primary supporting members
Irregularly stiffened panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate/PSM
Double bottom floors	SP-B	Length: full web depth Width: between primary supporting members
Vertical web frame including brackets	UP-B	Plate between vertical web stiffeners/face plate/PSM
Cross tie web plate	UP-B	Plate between vertical web stiffeners/face plate/PSM
Transverse oil-tight and watertight bulkheads, see Figure 3 and transverse wash bulkheads, see Figure 4		
Regularly stiffened bulkhead panels inclusive the secondary buckling stiffeners perpendicular to the regular stiffener (such as carlings)	SP-A	Length: between primary supporting members Width: between primary supporting members
Irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate
Web plate of bulkhead stringers including brackets	UP-B	Plate between web stiffeners /face plate
Transverse corrugated bulkheads and cross deck, see Figure 9		
Upper/lower stool including stiffeners	SP-A	Length: between internal web diaphragms Width: length of stool side
Stool internal web diaphragm	UP-B	Plate between local stiffeners /face plate / PSM

Structural elements	Assessment method	Normal panel definition
Cross deck	SP-A	Plate between local stiffeners/ PSM
Note1: SP and UP stand for stiffened and unstiffened panel respectively. Note2: A and B stand for Method A and Method B respectively.		

2.1.3 Yield stress of the plate panel

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

2.2 Stiffened panels

2.2.1

To represent the overall buckling behaviour, each stiffener with attached plate is to be modelled as a stiffened panel of the extent defined in Table 1.

2.2.2

If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

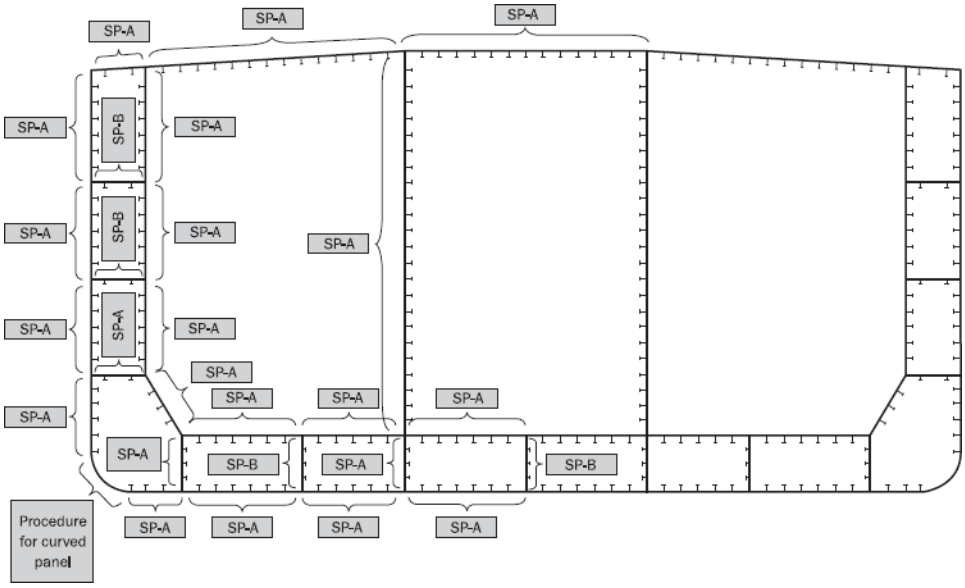


Figure 1 Longitudinal plates for oil tankers

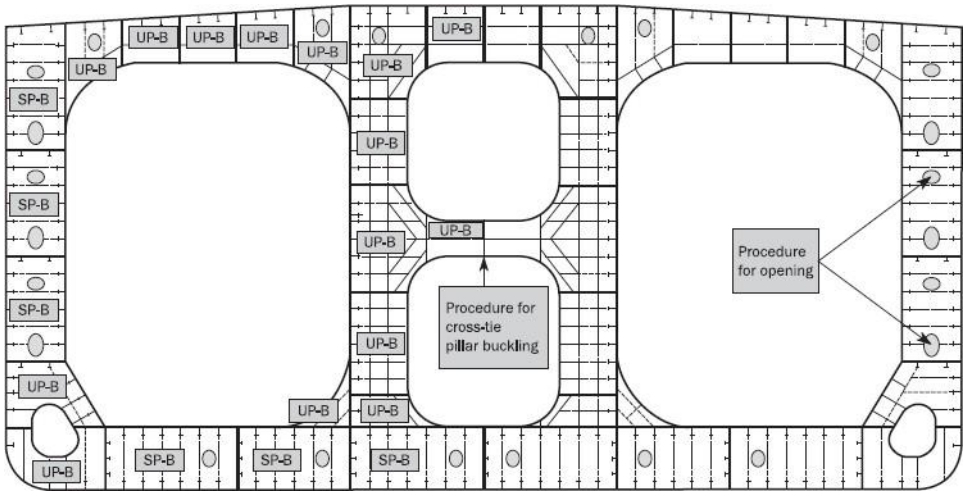


Figure 2 Transverse web frames for oil tankers

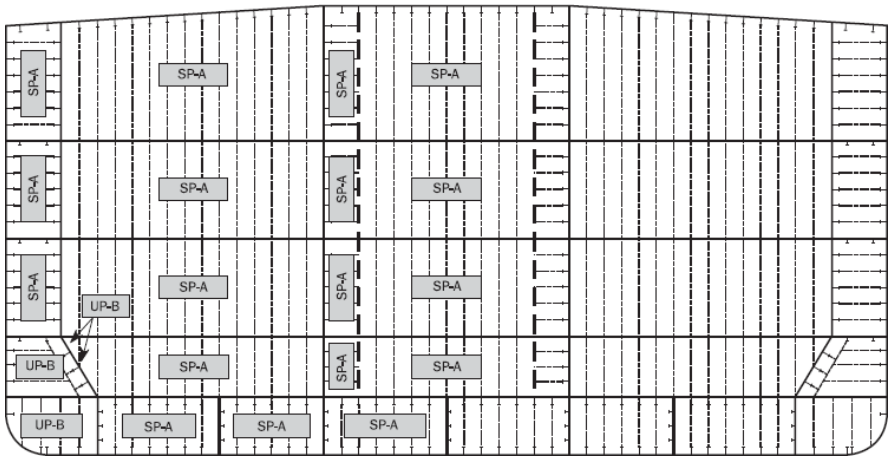


Figure 3 Transverse bulkhead for oil tankers

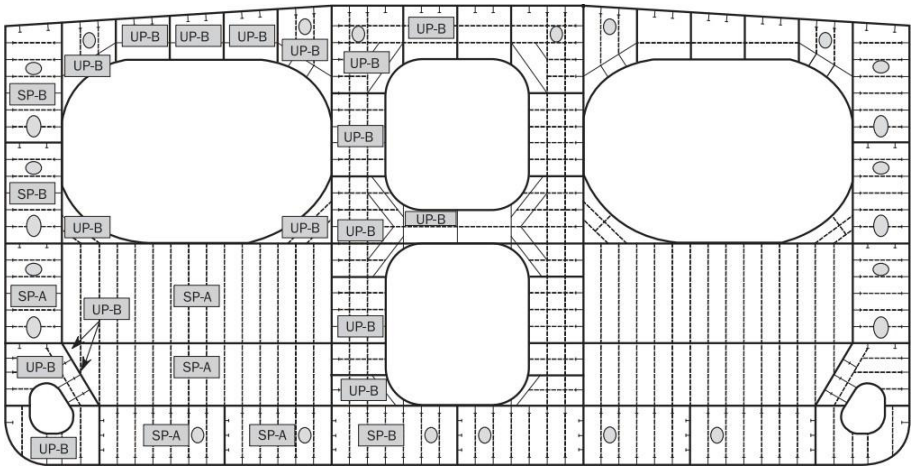


Figure 4 Cross tie

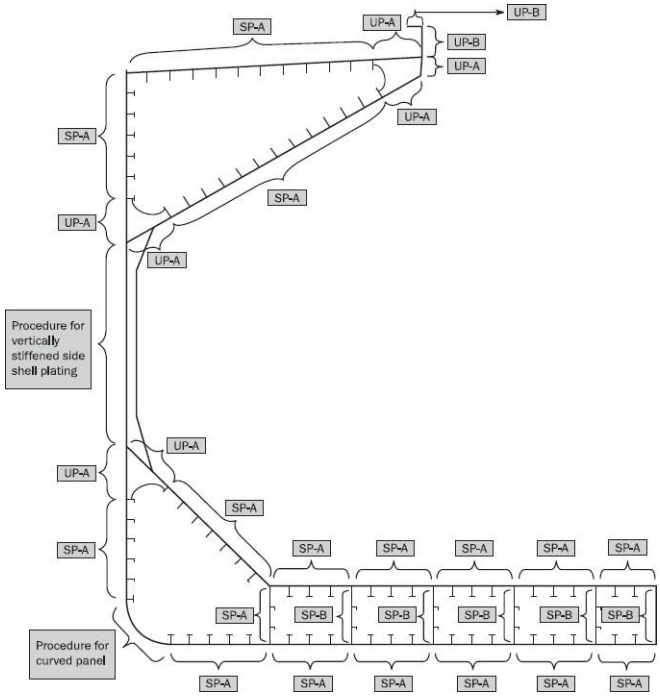


Figure 5 Longitudinal plates for single hull bulk carrier

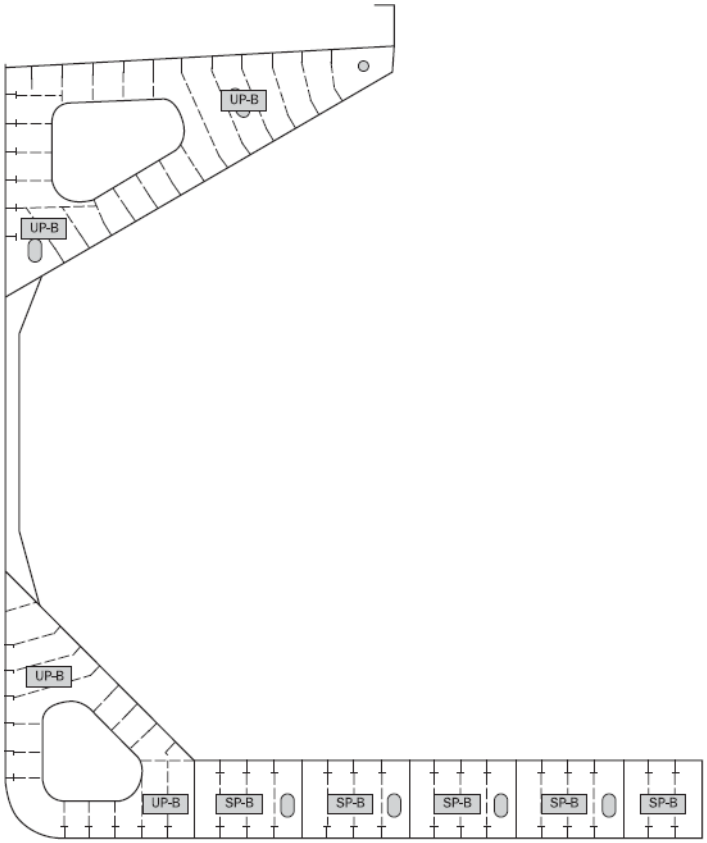


Figure 6 Transverse web frames for single hull bulk carrier

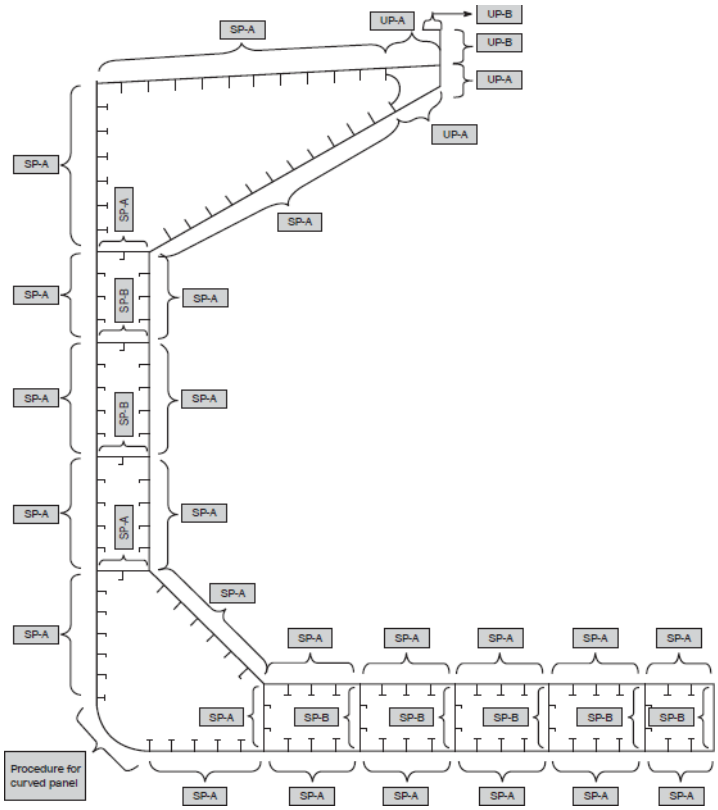


Figure 7 Longitudinal plates for double hull bulk carrier

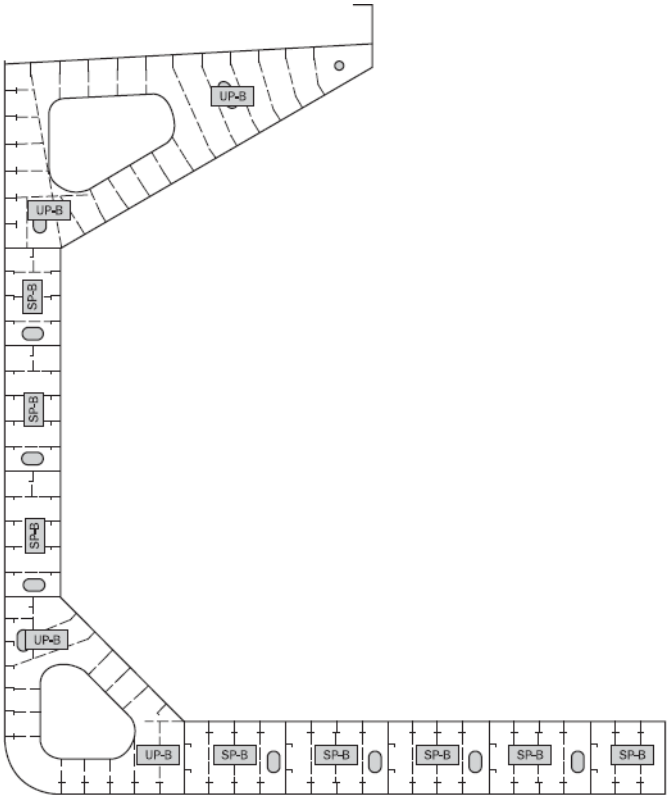


Figure 8 Transverse web frames for double hull bulk carrier

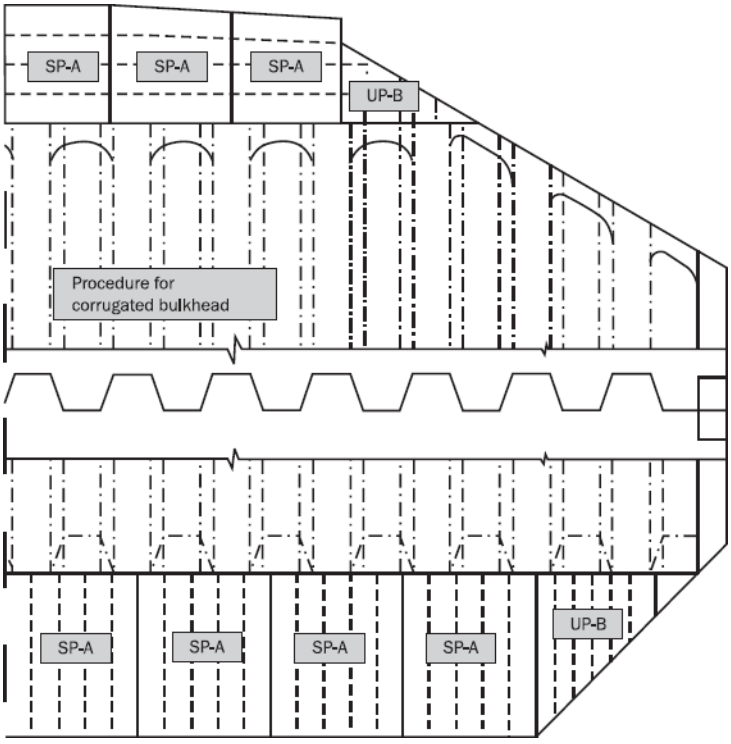


Figure 9 Corrugated bulkhead and cross deck for bulk carriers

2.3 Unstiffened panels

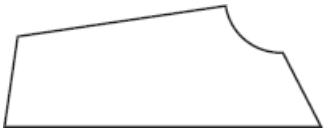
2.3.1 Irregular plate panel

In way of web frames, stringers and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [2.3.2] for irregular geometry and [2.3.3] for triangular geometry and to comply with buckling assessment.

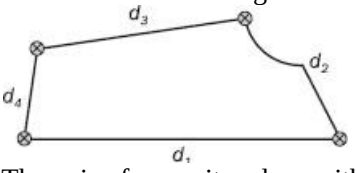
2.3.2 Modelling of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.

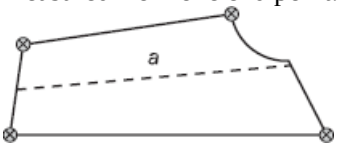


b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight line segments between the end points.



c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$

d) A line joins the middle points of the chosen opposite edges (i.e. a mid point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, a measured from one end point.



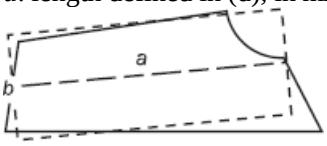
e) The length of shorter side, b in mm, is to be taken as:

$b = A/a$

where:

A: Area of the plate, in mm^2

a: length defined in (d), in mm

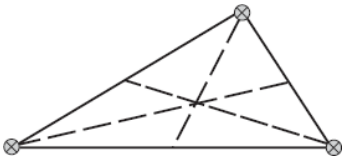


f) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

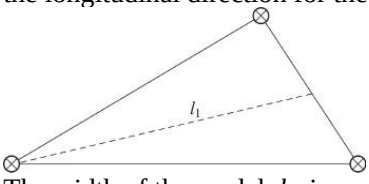
2.3.3 Modelling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) Medians are constructed as shown below.



b) The longest median is identified. This median the length of which is l_1, in mm, defines the longitudinal direction for the capacity model.

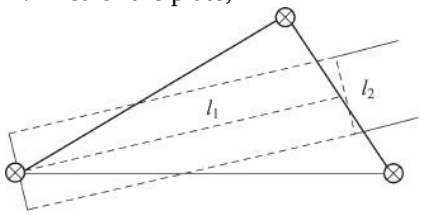


c) The width of the model, l_2, in mm, is to be taken as:

$l_2 = A / l_1$

where:

A: Area of the plate, in mm^2



d) The lengths of shorter side, *b*, and of the longer side, *a*, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$a = l_1 C_{tri}$

where:

$$C_{tri} = 0.4\frac{l_2}{l_1} + 0.6$$

e) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

2.4 Reference stress

2.4.1

The stress distribution is to be taken from the direct strength analysis and applied to the buckling model.

2.4.2

The reference stresses are to be calculated using the Stress based reference stresses as defined in App 1.

2.5 Lateral pressure

2.5.1

The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

2.5.2

Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, N/mm^2, is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

where:

A_i : Area of the *i*-th plate element, in mm^2.

P_i : Lateral pressure of the *i*-th plate element, in N/mm^2.

n : Number of finite elements in the buckling panel.

2.6 Buckling criteria

2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$\eta_{UP\text{-}A} \leqslant \eta_{all}$

where:

$\eta_{UP\text{-}A}$: Maximum plate utilisation factor, calculated according to Method A as defined in Ch 8, Sec 5, [2.2].

2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$\eta_{UP\text{-}B} \leqslant \eta_{all}$

where:

$\eta_{UP\text{-}B}$: Maximum plate utilisation factor, calculated according to Method B as defined in Ch 8, Sec 5, [2.2].

2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$\eta_{SP\text{-}A} \leqslant \eta_{all}$

where:

$\eta_{SP\text{-}A}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method A as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$\eta_{SP\text{-}B} \leqslant \eta_{all}$

where:

$\eta_{SP\text{-}B}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method B as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$\eta_{opening} \leqslant \eta_{all}$

where:

$\eta_{opening}$: Maximum web plate utilisation factor in way of openings, as defined in Ch 8, Sec 5, [2.4].

3 CORRUGATED BULKHEAD

3.1 General

3.1.1

Three buckling failure modes are to be assessed on corrugated bulkheads:

3.1.1 Corrugation overall column buckling.

3.1.2 Corrugation flange panel buckling.

3.1.3 Corrugation web panel buckling.

3.2 Reference stress

3.2.1

Each corrugation flange and web panel is to be assessed.

3.2.2

The membrane stresses at element centroid are to be used.

3.2.3

The maximum normal stress parallel to the corrugation, σ_x, is the maximum of the 2 following stresses:

- The normal stress parallel to the corrugation taken at $b/2$ from the corrugation ends,
- The normal stress parallel to the corrugation within the mid span of the corrugation.

When the corrugation end is fitted with a shedder plate, the normal stress parallel to the corrugation at end is to be taken at $b/2$ from the intersection of the shedder plate with the point at mid breadth of the flange or of the web, as the case may be.

The maximum shear stress is the shear stress which is maximum at the corrugation flange or web at the point

$b/2$ from ends as defined above for the normal stress parallel to the corrugation.

The in plane stresses, σ_x and σ_y, and shear stress, τ, are to be taken as the element stresses averaged over the width of the considered member (flange or web) at the considered location.

When the stress value at $b/2$ from ends cannot be obtained directly from FE element, the stress at this location is to be obtained by interpolation. This interpolation is to be made on elements extending over a distance equal to $3b$ to a point located at $b/2$ from the end of the corrugation or from the intersection of the shedder plate if fitted, measured at the mid breadth of the flange or of the web. The interpolation of the in plane stresses, σ_x and σ_y, are to be made in accordance with Ch 8, App 1, [2.1].

The shear stress at $b/2$ is obtained by linear interpolation between the elements most close to '$b/2$' location. For the application of this requirement, b is defined as follows:

b : Width of the considered member of the corrugation, i.e. flange or web.

3.2.4

Where more than one plate thicknesses are used for flange or web panel, maximum stress is to be obtained for each thickness range and to be checked with the buckling criteria for each thickness.

3.3 Overall column buckling

3.3.1

The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling (e.g. horizontally corrugated bulkheads and vertically corrugated bulkheads subjected to local vertical forces).

Application of overall column buckling for corrugated bulkhead **Table 2**

Bulkhead orientation	Corrugation Orientation	
	Horizontal	Vertical
Longitudinal bulkhead	Required	Required, when subjected to local vertical forces (e.g. crane loads)
Transverse bulkhead	Required	

3.3.2

Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 10) is to satisfy the following criterion:

$\eta_{Overall} \leqslant \eta_{all}$

where:

$\eta_{Overall}$: Maximum overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1.1] and Ch 8, Sec 5, [3.1.2], considered as a pillar with a unsupported length taken as the length of the corrugation.

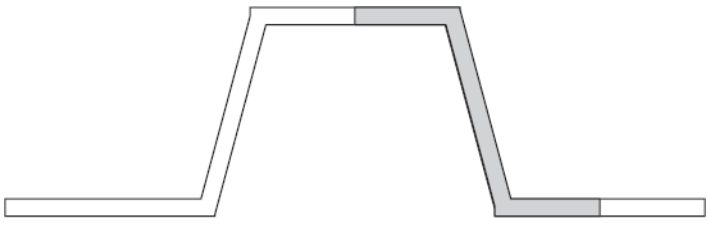


Figure 10 Single Corrugation

3.3.3
End constraint factor, f_{end} corresponding to pinned ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

3.4 Local buckling

3.4.1
The compressive buckling strength of a unit flange and a unit web of corrugation bulkheads is to satisfy the following criterion:

$\eta_{Corr} \leqslant \eta_{all}$

where:

η_{Corr} : Maximum unit flange or unit web utilisation factor, as defined in Ch 8, Sec 5, [3.2.1].

Two stress combinations are to be considered for the application of the above criterion:

3.4.1 The maximum normal stress parallel to the corrugation, σ_x, combined with the stress perpendicular to the corrugation, σ_y, and with the shear stress, τ, at the location where the maximum normal stress parallel to the corrugation occurs.

3.4.2 The maximum shear stress, τ, combined with the normal stress parallel to the corrugation, σ_x, and with the stress perpendicular to the corrugation, σ_y, at the location where the maximum shear stress occurs.

The buckling assessment is to be performed for an aspect ratio α equal to 2, and for the thicknesses of the member where the maximum compressive/shear stress occurs (see [3.2.4]).

4 VERTICALLY STIFFENED SIDE SHELL OF SINGLE SIDE SKIN BULK CARRIER

4.1 Buckling criteria

4.1.1 Side shell plating

The compressive buckling strength of the vertically stiffened side shell plating of single side skin bulk carrier is to satisfy the following criterion:

$\eta_{vss} \leqslant \eta_{all}$

where:

η_{vss}: Maximum vertically stiffened side shell plating utilisation factor calculated according to Method A as defined in Ch 8, Sec 5, [2.2.1] and considering the following boundary conditions and stress combinations:

- 4 edges simply supported (cases 1, 2 and 15 of Ch 8, Sec 5, Table 3):
  - Pure vertical stress:
    - The maximum vertical stress of stress elements is used with $\alpha = 1$ and $\Psi_x = 1$.
  - Maximum vertical stress combined with longitudinal and shear stress:
    - The maximum vertical stress in the buckling panel plus the shear and longitudinal stresses at the location where the maximum vertical stress occurs is used with $\alpha = 2$ and $\Psi_x = \Psi_y = 1$.
    - The plate thickness to be considered in the buckling strength check is the one where the maximum vertical stress occurs.
  - Maximum shear stress combined with longitudinal and vertical stress:
    - The maximum shear stress in the buckling panel plus the longitudinal and vertical stresses at the location where maximum shear stress occurs is used with $\alpha = 2$ and $\Psi_x = \Psi_y = 1$.
    - The plate thickness to be considered in the buckling strength check is the one where the maximum shear stress occurs.
- The 2 shorter edges of the plate panel clamped (cases 11, 12 and 16 of Ch 8, Sec 5, Table 3):
  - Distributed longitudinal stress associated with vertical and shear stress:
    - The actual size of the buckling panel is used to define α.
    - The average values for longitudinal, vertical and shear stresses are to be used.
    - $\Psi_x = \Psi_y = 1$.

- The plate thickness to be considered in the buckling strength check is the minimum thickness of the buckling panel.

4.1.2 Side frames

The buckling strength of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leqslant \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

5 STRUTS, PILLARS AND CROSS TIES

5.1 Buckling criteria

5.1.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta_{Pillar} \leqslant \eta_{all}$

The buckling strength of elementary plate panels of cross ties is to satisfy the following criterion:

$\eta_{Pillar} \leqslant \eta_{all}$

where:

η_{Pillar} : Maximum utilisation factor of struts, pillars or cross ties, as defined in Ch 8, Sec 5, [3.1].

η_{Plate} : Maximum plate utilisation factor calculated according to UP-B, as defined in Ch 8, Sec 5, [2.2].

Section 5 BUCKLING CAPACITY

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

A_s : Net sectional area of the stiffener without attached plating, in mm^2.

A_p : Net sectional area of the stiffener attached plating, in mm^2, taken as:

$A_p = st_p$

a : Length of the longer side of the plate panel, in mm.

b : Length of the shorter side of the plate panel, in mm.

b_{eff} : Effective width of the attached plating of a stiffener, in mm, as defined in [2.3.5].

b_{eff1} :Effective width of the attached plating of a stiffener, in mm, without the shear lag effect taken as:

- For $\sigma_x > 0$
  - For prescriptive assessment:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

  - For FE analysis:

$b_{eff1} = C_x b$

- For $\sigma_x \leq 0$

$b_{eff1} = b$

b_f : Breadth of the stiffener flange, in mm.

b_1, b_2 : Width of plate panel on each side of the considered stiffener, in mm.

C_{x1},C_{x2} : Reduction factor defined in Table 3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1.

d : Length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in Table 4, in mm.

d_f : Distance in mm, for the extension of flange for L2 profiles, as defined in Ch3, Sec2, Figure 3.

e_f : Distance from attached plating to centre of flange, in mm, as shown in Figure 1 to be taken as:

$e_f = h_w$ for flat bar profile.

$e_f = h_w - 0.5t_f$ for bulb profile.

$e_f = h_w + 0.5t_f$ for angle, L2 and Tee profiles.

F_{long} : Coefficient defined in [2.2.4].

F_{tran} : Coefficient defined in [2.2.5].

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

l : Span, in mm, of stiffener equal to spacing between primary supporting members or span of side frame equal to the distance between the hopper tank and top wing tank as defined in Pt 2, Ch 1, Sec 2, Figure 2.

R : Radius of curved plate panel, in mm.

R_{eH_P} : Specified minimum yield stress of the plate in N/mm^2.

R_{eH_S} : Specified minimum yield stress of the stiffener in N/mm^2.

S : Partial safety factor to be taken as:

- S = 1.1 for structures which are exposed to local concentrated loads (e.g. container loads on hatch covers, foundations).
- S = 1.15 for bulk carrier stiffeners located on the hatchway coamings, the sloping plate of the topside and hopper tanks, the inner bottom, the inner side if any, the side shell of single side skin construction and the top and bottom stools of transverse bulkheads.
- S = 1.0 for all other cases.

t_p : Net thickness of plate panel, in mm.

t_w : Net stiffener web thickness, in mm. t_f

: Net flange thickness, in mm.

x axis : Local axis of a rectangular buckling panel parallel to its long edge.

y axis : Local axis of a rectangular buckling panel perpendicular to its long edge.

α : Aspect ratio of the plate panel, defined in Table 3 to be taken as:

$$\alpha = \frac{a}{b}$$

β : Coefficient taken as:

$$\beta = \frac{1-\Psi}{\alpha}$$

ω : Coefficient taken as:

$\omega = \min(3;\sigma)$

σ_x : Stress applied on the edge along x axis of the buckling panel, in N/mm^2.

σ_y : Stress applied on the edge along y axis of the buckling panel, in N/mm^2.

σ_1 : Maximum stress, in N/mm^2.

σ_2 : Minimum stress, in N/mm^2.

σ_E : Elastic buckling reference stress, in N/mm^2 to be taken as:

- For the application of plate limit state according to [2.2.1]:

$$\sigma_E = \frac{\pi^2 E}{12(1-v^2)}\left(\frac{t_p}{b}\right)^2$$

- For the application of curved plate panels according to [2.2.6]:

$$\sigma_E = \frac{\pi^2 E}{12(1-v^2)}\left(\frac{t_p}{d}\right)^2$$

τ : Applied shear stress, in N/mm^2.

τ_c : Buckling strength in shear, in N/mm^2, as defined in [2.2.3].

ψ : Edge stress ratio to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

γ : Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$.

γ_c : Stress multiplier factor at failure.

γ_{GEB} : Stress multiplier factor of global elastic buckling capacity.

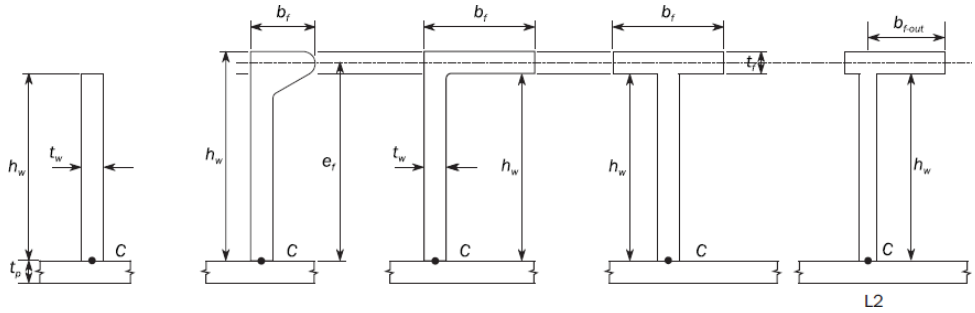


Figure 1 Stiffener cross sections

1 General

1.1 Scope

1.1.1

This section contains the methods for determination of the buckling capacity of plate panels, stiffeners, pri- mary supporting members, struts, pillars, cross ties and corrugated bulkheads.

1.1.2

For the application of this section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

- Ch 8, Sec 3 for prescriptive requirements.
- Ch 8, Sec 4 for FE analysis requirements.

1.1.3 Ultimate buckling capacity

The ultimate buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [2.1.1], [2.2.1], and [2.3.4] are equal to 1.0.

1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

1.1.5 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment.

2 Buckling Capacity of Plates and Stiffeners

2.1 Overall stiffened panel capacity

2.1.1

The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [2.3.4]:

$$\frac{\gamma}{\gamma_{GEB}} = 1$$

where the stress multiplier factor corresponding to global elastic buckling capacity, γ_{GEB} , is to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and ($\sigma x > 0$ or $\sigma y > 0$)

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and ($\sigma x > 0$ or $\sigma y > 0$)

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and ($\sigma x \leqslant 0$ and $\sigma y \leqslant 0$)

where $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$, and $\gamma_{GEB,\tau}$ are stress multiplier factors for different load combinations as defined in [2.1.2], [2.1.3] and [2.1.4], respectively. For the calculation of $\gamma_{GEB,i+\tau}$, $\gamma_{GEB,bi}$, and $\gamma_{GEB,\tau}$, neither σ_x nor σ_y shall be taken less than 0.

σ_x, σ_y : Applied normal stresses to the plate panel, in N/mm^2, to be taken as defined in [2.2.7].

τ : Applied shear stress, in N/mm^2, to be taken as defined in [2.2.7].

2.1.2

The stress multiplier factor $\gamma_{GEB,i}$, for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{\left[D_{11} L_{B2}^4 + 2(D_{12} + D_{33}) n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4 \right]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

N_x : Load per unit length applied on the edge along x axis of the stiffened panel, in N/mm, taken as

$$N_x = \sigma_{x,av}(A_p + A_s)/s$$

For stiffened panels fitted with U-type stiffeners, stiffener spacing s is taken as:

$$s = b_1 + b_2$$

Where b_1 and b_2 are as defined in Pt 2, Ch 1, Sec 5, Figure 1.

N_y : Load per unit length applied on the edge along y axis of the stiffened panel, in N/mm, taken as:

$N_y = c\sigma_y t_p$

L_{B1} : Stiffener span, in mm, equal to spacing between primary supporting members, i.e. $L_{B1} = l$. For vertically stiffened side shell of single side skin bulk carriers, $L_{B1} = 0.8l$.

L_{B2} : Width of the stiffened panel, in mm, taken as 6 times of the stiffener spacing, i.e. 6s.

n : Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,i}$ is to be minimized with respect to the wave parameter n, i.e. to be taken as the smallest value larger than zero.

c : Factor taking into account the stresses in the attached plating acting perpendicular to the stiffener axis:

$c = 0.5(1+\psi)$ for $0 \leqslant \Psi \leqslant 1$

$c = \frac{1}{2(1-\psi)}$ for $\Psi < 0$

ψ : Edge stress ratio for case 2 according to Table 3.

$\sigma_{x,av}$: Average stress for both plate and stiffener with Poisson correction, taken as:

$$\sigma_{x,\ av} = \sigma_x - vc\sigma_v A_s / (A_p + A_s) \geq 0 \qquad \text{for } \sigma_x>0 \text{ and } \sigma_y>0$$

$\sigma_{x,av}=\sigma_x$ for $\sigma_x \leqslant 0$ or $\sigma_y \leqslant 0$

D_{11},D_{12},D_{22},D_{33} : Bending stiffness coefficients, in Nmm, of the stiffened panel, defined in general as:

$$D_{11} = \frac{EI_{eff}10^4}{S}$$

$$D_{12} = \frac{Et_p^{\ 3}v}{12\left(1-v^2\right)}$$

$$D_{22} = \frac{Et_p^{\ 3}}{12\left(1-v^2\right)}$$

$$D_{33} = \frac{Et_p^{\ 3}}{12\left(1+v\right)}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-v^2)}\left[1.2 + 4.8 \times \text{Min}\left(1.0, \frac{b_1^2}{h_w(b_1+b_2)}\right) \times \text{Min}\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = vD_{22}$$

h_w : Breadth of U-type stiffener web as defined in Pt 2, Ch 1, Sec 5, Figure 1.

I_{eff} : Moment of inertia, in cm^4, of the stiffener including effective width of attached plating, the same as I defined in [2.3.4].

2.1.3

The stress multiplier factor $\gamma_{GEB,\tau}$ for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}}\left[8.125 + 5.64\sqrt{\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}} - 0.6\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}\right] \qquad \text{for } D_{11}D_{22} \geqslant (D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12}+D_{33})}}{(L_{B1}/2)^2 N_{xy}}\left[8.3 + 1.525\sqrt{\frac{D_{11}D_{22}}{(D_{12}+D_{33})^2}} - 0.493\frac{D_{11}^{\ 2}D_{22}^{\ 2}}{(D_{12}+D_{33})^4}\right] \qquad \text{for } D_{11}D_{22} < (D_{12}+D_{33})^2$$

where

$N_{xy}=\tau t_p$

2.1.4

The stress multiplier factor $\gamma_{GEB,i+i}$ for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,\text{bi+}\tau} = \frac{1}{2}\gamma_{GEB,\tau}^{\ 2}\left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{\gamma_{GEB,bi}^{\ 2}} + 4\frac{1}{\gamma_{GEB,\tau}^{\ 2}}}\right]$$

where $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [2.1.2] and [2.1.3], respectively.

2.2 Plate capacity

2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}^{'}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}^{'}}\right)^{e_0/2}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}^{'}}\right)^{e_0/2} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}^{'}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau| S}{\tau_c^{'}}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}^{'}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c2}|\tau| S}{\tau_c^{'}}\right)^{2/\beta_p^{0.25}} = 1 \text{ for } \sigma_x \geqslant 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cx}^{'}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c^{'}}\right)^{2/\beta_p^{0.25}} = 1 \text{ for } \sigma_y \geqslant 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c^{'}} = 1$$

with

$\gamma_c = \min(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$

where:

σ_x, σ_y : Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [2.2.7].

τ : Applied shear stress to the plate panel, in N/mm^2.

$\sigma_{cx}^{'}$: Ultimate buckling stress, in N/mm^2, in direction parallel to the longer edge of the buckling panel as defined in [2.2.3].

$\sigma_{cy}^{'}$: Ultimate buckling stress, in N/mm^2, in direction parallel to the shorter edge of the buckling panel as defined in [2.2.3].

$\tau_c^{'}$: Ultimate buckling shear stresses, in N/mm^2, as defined in [2.2.3].

γ_{c1}, γ_{c2}, γ_{c3}, γ_{c4}: Stress multiplier factors at failure for each of the above different limit states. γ_{c1} and γ_{c2} are only to be considered when $\sigma_x \geqslant 0$ and $\sigma_y \geqslant 0$ respectively.

B : Coefficient given in Table 1.

e_0 : Coefficient given in Table 1.

β_p :Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$$

Definition of coefficients *B* and e_0 **Table 1**

Applied Stress	B	e_0
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7\text{-}0.3\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where:

K : Buckling factor, as defined in Table 3 and Table 4.

2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm^2, are to be taken as:

$$\sigma_{cx}' = C_x R_{eH_P}$$

$$\sigma_{cy}' = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm^2, is to be taken as:

$$\tau_c^{'} = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where:

C_x, C_y, C_τ :Reduction factors, as defined in Table 3

- For the 1st Equation of [2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to taken as: $C_x = C_y = C_\tau = 1$.
- For the other cases:
  - For SP-A and UP-A, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

  - For SP-B and UP-B, C_y is calculated according to Table 3 by using

$c_1 = 1$

- For vertically stiffened single side skin of bulk carrier, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

For corrugation of corrugated bulkheads, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

The boundary conditions for plates are to be considered as simply supported, see cases 1, 2 and 15 of Table 3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 3 subject to the agreement of the Society.

2.2.4 Correction factor Flong

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 2. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 2, the value of c is to be agreed by the Society. In such a case, value of c higher than those mentioned in Table 2 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by the Society.

Correction factor F_{long} **Table 2**

<table>
<tr><th colspan="3">Structural element types</th><th>F_{long}</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="7">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="6">Stiffener fixed at both ends</td><td>Flat bar (1)</td><td rowspan="4">$F_{long}=c$ for $\frac{t_w}{t_p} > 1$
$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1$ for $\frac{t_w}{t_p} \leq 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle and L2 profiles</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover (2)</td><td>• Plate on which the U type profile is fitted, including EPP b_1 and EPP b_2
  • For $b_2 < b_1$: $F_{long}=1$
  • For $b_2 \geq b_1$: $F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$
• Other plate of the U type profile: $F_{long}=1$</td><td>0.2</td></tr>
<tr><td colspan="5">(1) t_w is the net web thickness, in mm, without the correction defined in [2.3.2].
(2) b_1 and b_2 are defined in Pt 2, Ch 1, Sec 5,Figure 1.</td></tr>
</table>

ISC 2.2.4a The correction factor, F_{long} , of U type stiffened panel in hatch cover is calculated in accordance with the following formula:

$$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$$

where: b_1— width of opening of U type, in mm, see Figure ISC 2.2.4a;

b_2 — *web spacing of two adjacent U type, in mm, see Figure ISC 2.2.4a;*
c =0.2, when $b_2 \geqslant b_1$

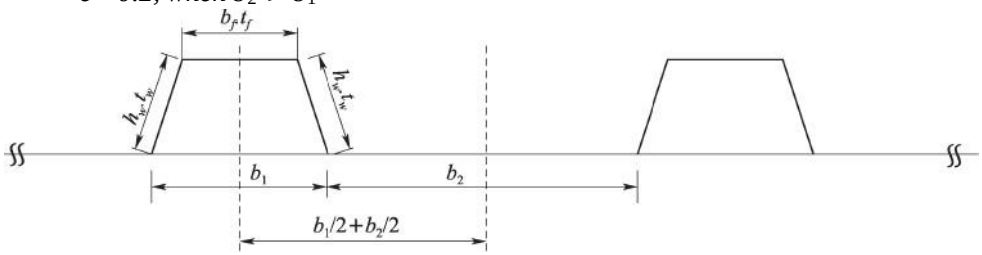


Figure ISC 2.2.4a U Type of Hatch Cover

2.2.5 Correction factor Ftran

The correction factor F_{tran} is to be taken as:

- For transversely framed EPP of single side skin bulk carrier, between the hopper and top wing tank:
  - F_{tran} = 1.25 when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels.
  - F_{tran} = 1.33 when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.
  - F_{tran} = 1.15 elsewhere.
- For the attached plate of a U-type stiffener fitted on a hatch cover:

$$F_{tran} = \text{Max}\left(3 - 0.08(F_{tran0} - 6)^2, 1.0\right) \leq 2.25$$

where,

$$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \quad \text{for EPP } b_2$$

$$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \quad \text{for EPP } b_1$$

with b_1, b_2 and h_w as defined in Pt 2, Ch 1, Sec 5, Figure 1.
Coefficient F defined in Case 2 of Table 3 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0.91 F_{tran}} - 1\right) / \lambda_p^2\right] c_1 \geq 0$$

- For other cases: F_{tran} = 1

2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in [2.2.1] is applicable.
The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)^{1.25} - 0.5\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

where:

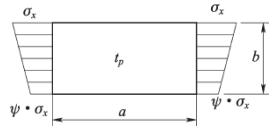
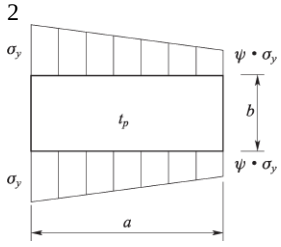
σ_{ax} : Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm^2.In case of tensile axial stresses, σ_{ax} = 0.

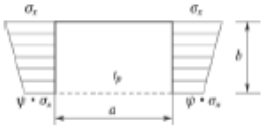
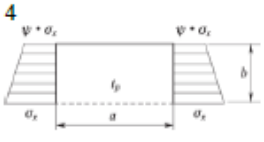
σ_{tg} : Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile tangential stresses, σ_{tg} = 0.

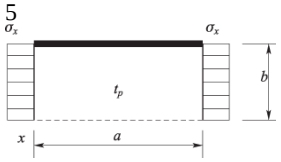
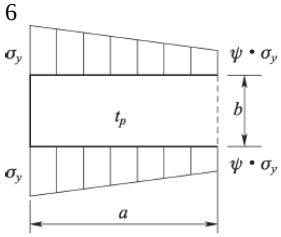
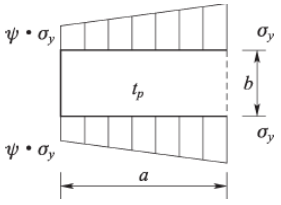
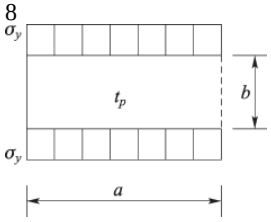
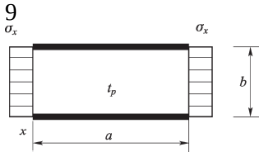
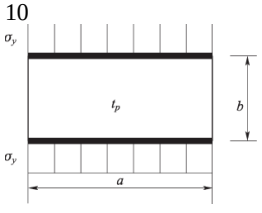
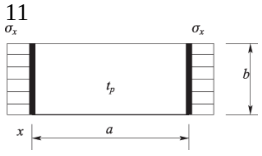
C_{ax}, C_{tg}, C_τ: Buckling reduction factor of the curved plate panel, as defined in Table 4.

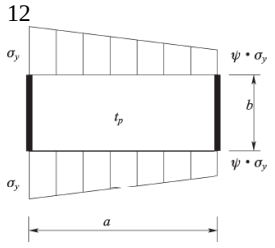
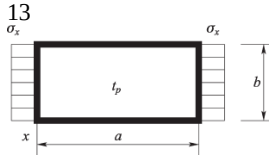
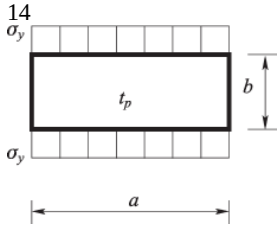
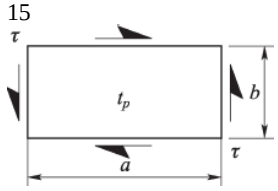
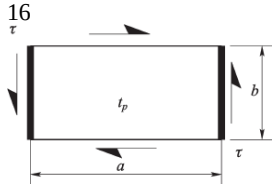
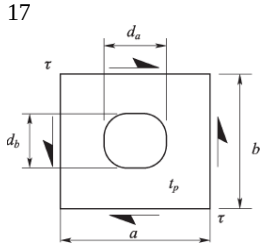
The stress multiplier factor, γ_c, of the curved plate panel need not be taken less than the stress multiplier factor, γ_c, for the expanded plane panel according to [2.2.1].

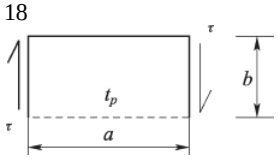
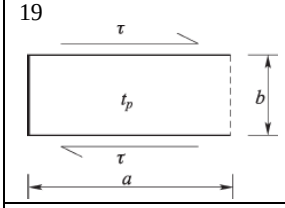
Buckling factor and reduction factor for plane plate panels **Table 3**

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
1  	$1 \geqslant \psi \geqslant 0$		$K_x = F_{longa}\dfrac{8.4}{\psi + 1.1}$	When $\sigma_x \leqslant 0$ C_x=1 When σ_x>0 C_x = 1 for $\lambda \leqslant \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where: $c = (1.25\text{-}0.12\psi) \leqslant 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K_x = F_{long}[7.63\text{-}\Psi(6.26\text{-}10\psi)]$	
	$\psi \leqslant -1$		$K_x = F_{long}[5.975(1\text{-}\psi)^2]$	
2  	$1 \geqslant \psi \geqslant 0$		$K_y = F_{tran}\dfrac{2\left(1 + \dfrac{1}{\alpha^2}\right)^2}{1 + \psi + \dfrac{(1-\psi)}{100}\left(\dfrac{2.4}{\alpha^2} + 6.9 f_1\right)}$	When $\sigma_y \leqslant 0$ C_y=1; When σ_y >0 $C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H-R)}{\lambda^2}\right)$ Where: c=(1.25-0.12Ψ)$\leqslant$1.25 $R = \lambda(1\text{-}\lambda/c)$ for $\lambda < \lambda_c$ R = 0.22 for $\lambda \geqslant \lambda_c$ $\lambda_c = 0.5c\left(1 + \sqrt{1 - 0.88/c}\right)$ $F = \left(1 - \left(\dfrac{K}{0.91} - 1\right)\Big/\lambda_p^2\right)c_1 \geq 0$ $F = \left(1 - \left(\dfrac{K}{0.91} - 1\right)\Big/\lambda_p^2\right)c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leqslant \lambda_p^2 \leqslant 3$ c_1 as defined in [2.2.3] $H = \lambda - \dfrac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
		$\alpha \leqslant 6$	$f_1 = (1\text{-}\Psi)(\alpha\text{-}1)$	
		$\alpha > 6$	$f_1 = 0.6\left(1 - \dfrac{6\psi}{a}\right)\left(a + \dfrac{14}{a}\right)$ but not greater than $14.5 - \dfrac{0.35}{a^2}$	
	$0 > \psi \geq 1 - \dfrac{4\alpha}{3}$		$K_y = \dfrac{200 F_{tran}(1 + \beta^2)^2}{(1 - f_3)(100 + 2.4\beta^2 + 6.9 f_1 + 23 f_2)}$	
		$\alpha > 6(1\text{-}\psi)$	$f_1 = 0.6\left(\dfrac{1}{\beta} + 14\beta\right)$ but not greater than $14.5\text{-}0.35\beta^2$ f_2=f_3=0	
		$3(1\text{-}\psi) \leqslant \alpha \leqslant 6(1\text{-}\psi)$	$f_1 = \dfrac{1}{\beta} - 1$ f_2=f_3=0	

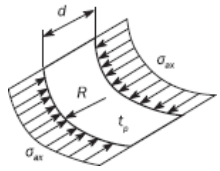
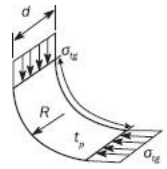
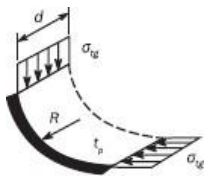
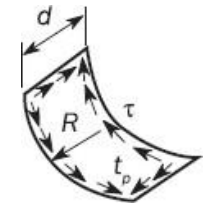
Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
		$1.5(1-\psi) \leqslant \alpha < 3(1-\psi)$	$f_1 = \frac{1}{\beta} - (2-\omega\beta)^4 - 9(\omega\beta-1)(\frac{2}{3}-\beta)$ f_2=f_3=0	
		$1-\psi \leqslant \alpha < 1.5(1-\psi)$	• For α>1.5 $f_1 = 2\left(\frac{1}{\beta} - 16\left(1-\frac{\omega}{3}\right)^4\right)(\frac{1}{\beta}-1)$ f_2=3β-2=0 f_3=0 • For $\alpha \leqslant$1.5 $f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$ $f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$ f_3=0 f_4= (1.5-Min(1.5;α))^2	
		$0.75(1-\psi) \leqslant \alpha < 1-\psi$	f_1=0 $f_2 = 1+2.31(\beta-1)-48\left(\frac{4}{3}-\beta\right)f_4^2$ $f_3 = 3f_4(\beta-1)-\left(\frac{f_4}{1.81}-\frac{\alpha-1}{1.31}\right)$ f_4= (1.5-Min(1.5;α))^2	
	$\psi < 1-\frac{4\alpha}{3}$		$K_y = 5.972F_{tran}\frac{\beta^2}{1-f_3}$ where $f_3 = f_5\left(\frac{f_5}{1.81}+\frac{1+3\psi}{5.24}\right)$ $f_5 = \frac{9}{16}(1+\text{Max}(-1;\psi))^2$	
3 	$1 \geqslant \psi \geqslant 0$		$K_x = \frac{4(0.425+1/\alpha^2)}{3\psi+1}$	For UP-A: C_x= 1 for $\lambda \leqslant 0.75$ $C_x = \frac{0.75}{\lambda}$ for λ>0.75 For UP-B: C_x= 1 for $\lambda \leqslant 0.7$ $C_x = \frac{1}{\lambda^2+0.51}$ for λ > 0.7
	$0 > \psi > -1$		K_x=4(0.425+1/α^2)(1+ψ)-5ψ(1-3.42ψ)	
4 	$1 \geqslant \psi \geqslant -1$		$K_x = \left(0.425+\frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$	

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
5 	—	$\alpha \geqslant 1.64$	K_x=1.28	
		$\alpha < 1.64$	$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
6 	$1 \geqslant \psi \geqslant 0$		$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$	For UP-A: $C_y = 1$ for $\lambda \leqslant 0.75$ $C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$ For UP-B: $C_x = 1$ for $\lambda \leqslant 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geqslant -1$		$K_y = 4(0.425+\alpha^2)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$	
7 	$1 \geqslant \psi \geqslant -1$		$K_y = (0.425+\alpha^2)\frac{(3-\psi)}{2\alpha^2}$	
8 	—		$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	
9 	—		K_x=6.97	$C_x = 1$ for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
10 	—		$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_x = 1$ for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
11 	—	$\alpha \geqslant 4$	K_x= 4	$C_x = 1$ for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ For $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$	

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
12  	—	K_y=K_y determined as per case 2		For $\alpha < 2$: C_y=C_{y2} For $\alpha \geqslant 2$ $C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$ Where: C_{y2} : C_y determined as per case 2
13  	—	$\alpha \geqslant 4$	K_x= 6.97	C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$	
14  	—	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2}\left[\frac{4-1/\alpha}{3}\right]^4$		C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
15  	—	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$		
16  	—	$K_\tau = \sqrt{3}\left[5.34 + \text{Max}\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right]$		C_τ = 1 for $\lambda \leqslant 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
17  	—	K_τ=$K_{\tau case15}$$r$ $K_{\tau case15}$: K_τ according to case 15 r : Opening reduction factor taken as $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ With $\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$		

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
18 	—	$K_\tau = \sqrt{3}\left(0.6+4/\alpha^2\right)$		$C_\tau = 1$ for $\lambda \leqslant 0.84$ $C_\tau = \dfrac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	—	$K_\tau = 8$		
Edge boundary conditions: Plate edge free. Plate edge simply supported. Plate edge clamped.				
Note 1: Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.				

Buckling and reduction factor for curved plate panel with $R/t_p \leqslant 2500$ Table 4

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \leq 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: C_{ax}=1 for $\lambda \leqslant 0.25$ C_{ax}=1.233-0.933λ for $0.25 < \lambda \leqslant 1$ C_{ax}=0.3/λ^2 for $1 < \lambda \leqslant 1.5$ C_{ax}=0.2/λ^2 for $\lambda > 1.5$ For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Ch 6, Sec 4, Figure 1: $C_{ax} = \frac{0.65}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \geq 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \leq 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: C_{tg}=1 for $\lambda \leqslant 0.4$ C_{tg}=1.274-0.686λ for $0.4 < \lambda \leqslant 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Ch6, Sec 4, Figure 1: $C_{tg} = \frac{0.8}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$	
3 	$\frac{d}{R} \leq \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2a.
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R}{dt_p}\right)^2$	
4 	$\frac{d}{R} \leq 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	C_τ=1 for $\lambda \leqslant 0.4$ C_τ=1.274-0.686λ for $0.4 < \lambda \leqslant 1.2$ $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	

Explanations for boundary conditions:
- - - - - - - - - - Plate edge free.
———————Plate edge simply supported
▬▬▬▬▬▬▬▬ Plate edge clamped.

2.2.7 Applied normal and shear stresses to plate panels

The normal stresses, σ_x and σ_y, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in in [2.1.1] and [2.2.1] respectively, are to be taken as follows:

- For FE analysis, the reference stresses as defined in Ch 8, Sec 4, [2.4].

- For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in Ch 3, Sec 7, [3] and [2], respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in Ch 3, Sec 7, [2].
- For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1-\nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1-\nu^2}$$

Where:

σ_{xb}, σ_{yb} : Stress, in N/mm^2, from grillage beam analysis respectively along *x* or *y* axis of the plate attached to the PSM web.

The shear stress τ, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in in [2.1.1] and [2.2.1] respectively ,are to be taken as follows:

- For FE analysis, the reference shear stresses as defined in Ch 8, Sec 4, [2.4].
- For prescriptive assessment of the plate panel capacity, the shear stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered elementary plate panel, as defined in Ch 3, Sec 7, [2].
- For prescriptive assessment of the overall stiffened panel capacity, the shear stresses calculated according to Ch 8, Sec 3, [2.2.1], at the following load calculation point:
  - At the middle of the full span, *ll*, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plating.
- For grillage beam analysis, τ= 0 in the plate attached to the PSM web.

2.3 Stiffeners

2.3.1 Buckling modes

The following buckling modes are to be checked:

- Stiffener induced failure (*SI*).
- Associated plate induced failure (*PI*).

2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used in [2.1] and [2.3.4] for the calculation of the net sectional area, *As*, the net section modulus, *Z*, and the moment of inertia, *I*, of the stiffener and is taken as:

$$t_{w_red} = t_w\left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1 - \frac{b_{eff1}}{s}\right)\right)$$

2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles, as defined in Ch 3, Sec 7, [1.4.1].

2.3.4 Ultimate buckling capacity

When $\sigma_a+\sigma_b+\sigma_w>0$ while initially setting γ = 1, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c\sigma_a + \sigma_B + \sigma_w}{R_{eH}} S = 1$$

where:

σ_a : Effective axial stress, in N/mm^2, at mid span of the stiffener, acting on the stiffener with its

attached plating.

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1} t_p + A_s}$$

σ_x : Nominal axial stress, in N/mm^2, acting on the stiffener with its attached plating.

- For FE analysis, σ_x is the FE corrected stress as defined in [2.3.6] in the attached plating in the direction of the stiffener axis.
- For prescriptive assessment, σ_x is the axial stress calculated according to Ch 8, Sec 3, [2.2.1] at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].
- For grillage beam analysis, σ_x is the stress acting along the x-axis of the attached buckling panel.

R_{eH} : Specified minimum yield stress of the material, in N/mm^2:

$R_{eH} = R_{eH_S}$ for stiffener induced failure (*SI*).

$R_{eH} = R_{eH_P}$ for plate induced failure (*PI*).

σ_b : Bending stress in the stiffener, in N/mm^2:

$$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}$$

Z : Net section modulus of stiffener, in cm^3, including effective width of plating according to [2.3.5], to be taken as:

- The section modulus calculated at the top of stiffener flange for stiffener induced failure (*SI*).
- The section modulus calculated at the attached plating for plate induced failure (*PI*).

C_{PI} : Plate induced failure pressure coefficient:

C_{PI} = 1 if the lateral pressure is applied on the side opposite to the stiffener.

C_{PI} = -1 if the lateral pressure is applied on the same side as the stiffener.

C_{SI} : Stiffener induced failure pressure coefficient:

C_{SI} = -1 if the lateral pressure is applied on the side opposite to the stiffener.

C_{SI} = 1 if the lateral pressure is applied on the same side as the stiffener.

M_2 : Bending moment, in Nmm, due to eccentricity of sniped stiffeners, to be taken as

M_2=0 for continuous stiffeners

$M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.

C_{snip} : Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as

C_{snip}= -1.2 for stiffener induced failure (*SI*)

C_{snip}= 1.2 for plate induced failure (*PI*).

M_1 : Bending moment, in Nmm, due to the lateral load P:

$$M_1 = C_i \frac{|P| s l^2}{24 \times 10^3} \text{ for continuous stiffener}$$

$$M_1 = C_i \frac{|P| s l^2}{8 \times 10^3} \text{ for sniped stiffener}$$

$$M_1 = C_i \frac{|P| s l^2}{14.2 \times 10^3} \text{ for stiffener sniped at one end and continuous at the other end}$$

P : Lateral load, in kN/m^2.

- For FE analysis, P is the average pressure as defined in Ch 8, Sec 4, [2.5.2] in the attached plating.
- For prescriptive assessment, P is the pressure calculated at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].

C_i : Pressure coefficient:

$C_i = C_{SI}$ for stiffener induced failure (*SI*).

$C_i = C_{PI}$ for plate induced failure (*PI*).

M_0 : Bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0 \quad \text{with precondition } \gamma_{GEB} - \gamma > 0$$

where γ_{GEB} is the stress multiplier factor of global elastic buckling capacity as defined in [2.1].

C_{sl} : Deformation reduction factor to account for global slenderness, to be taken as:

$$C_{sl} = 1 - \frac{1}{12}\lambda_G^4 \qquad \text{for } \lambda \leqslant 1.56$$

$$C_{sl} = 3/\lambda_G^4 \qquad \text{for } \lambda > 1.56$$

λ_G : The reference degree of global slenderness of the stiffened panel, to be taken as

$$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}} \quad \text{and} \quad \gamma_{ReH} = \frac{\min(R_{eH_P}, R_{eH_S})}{\sqrt{\sigma_{x,av}^2 + \sigma_y^2 - \sigma_{x,av}\sigma_y + 3\tau_{xy}^2}}$$

F_E : Ideal elastic buckling force of the stiffener, in N

$$F_E = \left(\frac{\pi}{l}\right)^2 EI \cdot 10^4$$

I : Moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to [2.3.5]. I is to comply with the following requirement:

$$I \geq \frac{st_p^3}{12 \cdot 10^4}$$

t_p : Net thickness of plate, in mm, to be taken as

- For prescriptive requirements: the mean thickness of the two attached plating panels,
- For FE analysis: the thickness of the considered EPP on one side of the stiffener.

w_0 : Assumed imperfection, in mm, to be taken as:

$w_0 = l/1000$

w_{na} : Distance from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to [2.3.5].

σ_w : Stress due to torsional deformation, in N/mm^2, to be taken as:

- For stiffener induced failure (*SI*)
  - For $\sigma_a > 0$

$$\sigma_w = Ey_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1 - \frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right) \quad \text{for with precondition } \sigma_{ET} - \gamma\sigma_a > 0$$

  - For $\sigma_a \leqslant 0$

    $\sigma_w = 0$
- For plate induced failure (*PI*)

  $\sigma_w = 0$

l_{tor} : Stiffener span, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, l_{tor} should be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

y_w : Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

$$y_w = \frac{t_w}{2} \qquad \text{for flat bar}$$

$$y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s} \qquad \text{for angle and bulb profiles}$$

$$y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f(b_f^2 - 2b_f d_f)}{2A_s} \qquad \text{for L2 profile}$$

$$y_w = \frac{b_f}{2} \qquad \text{for T profile.}$$

Φ_0 : Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor} h_w} 10^{-4}$$

σ_{ET} : Reference stress for torsional buckling, in N/mm^2:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 I_w \cdot 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \cdot 10^{-4}\right]$$

I_P : Net polar moment of inertia of the stiffener, in cm^4, about point *C* as shown in Figure 1, as defined in Table 5.

I_T : Net St. Venant's moment of inertia of the stiffener, in cm^4, as defined in Table 5.

I_ω : Net sectorial moment of inertia of the stiffener, in cm^6, about point *C* as shown in Figure 1, as defined in Table 5

m_{tor} : Number of half waves within $lltttttt$, taken as a positive integer so as to give smallest reference stress for torsional buckling.

ε : Degree of fixation.

$$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1} \qquad \text{for bulb,angle,L2 ,L3 and T profiles;}$$

$$\varepsilon = \left(\frac{t_p^3}{3b}\right) \qquad \text{for flat bars.}$$

A_w : Net web area, in mm^2.

A_f : Net flange area, in mm^2.

Moments of inertia **Table 5**

	Flat bars (1)	Bulb, angle , L2 and T profiles
I_P	$\frac{h_w^3 t_w}{3 \cdot 10^4}$	$\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2\right)10^{-4}$
I_T	$\frac{h_w t_w^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f - 0.5t_f)t_w^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right) + \frac{b_f t_f^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36 \cdot 10^6}$	For bulb, angle and L2 profiles(2). $\frac{A_f^3 + A_w^3}{36 \cdot 10^6} + \frac{e_f^2}{10^6}\left(\frac{A_f b_f^2 + A_w t_w^2}{3} - \frac{\left(A_f(b_f - 2d_f) + A_w t_w\right)^2}{4(A_f + A_w)} - A_f d_f (b_f - d_f)\right)$ For T profiles $\frac{b_f^3 t_f e_f^2}{12 \cdot 10^6}$

(1) t_w is the net web thickness, in mm. t_{w_red} as defined in [2.3.2] is not to be used in this table.
(2) d_f is to be taken as 0 for bulb and angle profiles.

2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, b_{eff}, in mm, is to be taken as:

- For $\sigma_x > 0$:
  - For FE analysis,
    $b_{eff} = \min(C_x b, \chi_s s)$
  - For prescriptive assessment,

$$b_{eff} = \min\left(\frac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s\right)$$

- For $\sigma_x \leqslant 0$:
  - $b_{eff} = \chi_s s$

where:

χ_s : Effective width coefficient to be taken as:

$$\chi_s = \min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{l_{eff}}{s}\right)^{1.6}}}; 1.0\right]$$

l_{eff} : Effective length of the stiffener, in mm, taken as:

$l_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends.

$l_{eff} = 0.75l$ for stiffener simply supported at one end and fixed at the other.

$l_{eff} = l$ for stiffener simply supported at both ends.

2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Ch 8, Sec 4, [2.4] are both com- pressive, σ_x is to be corrected according to the following formula:

- If $\sigma_x < \nu\sigma_y$:
  $\sigma_{xcor} = 0$
- If $\sigma_x \geqslant \nu\sigma_y$:
  $\sigma_{xcor} = \sigma_x - \nu\sigma_y$

2.4 Primary supporting members

2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the com- bined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 6.

The interaction formulae of [2.2.1] are to be used with:

- $\sigma_x = \sigma_{av}$
- $\sigma_y = 0$
- $\tau = \tau_{av}$

where:

σ_{av} : Weighted average compressive stress, in N/mm^2, in the area of web plate being considered , i.e. P1, P2,or P3 as shown in Table 6.,

For the application of the Table 6, the weighted average shear stress is to be taken as:

- Opening modelled in primary supporting members:
  τ_{av}: Weighted average shear stress, in N/mm^2, in the area of web plate being considered , i.e. P1, P2,or P3 as shown in Table 6.
- Opening not modelled in primary supporting members:
  τ_{av}: Weighted average shear stress, in N/mm^2, given in Table 6.

2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combination with, C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 6.

2.4.3

The equivalent plate panel of web plate of primary supporting members crossed by perpendicular

stiffeners is to be idealised as shown in Figure 2.

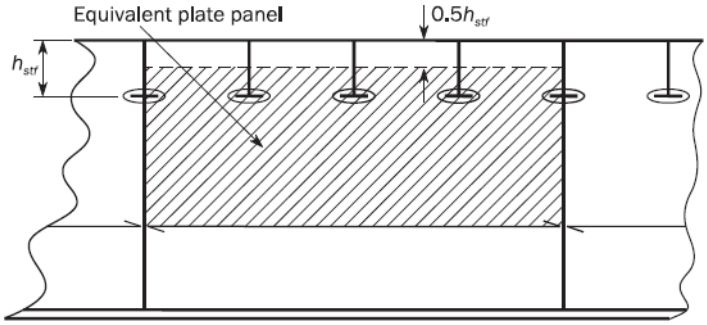
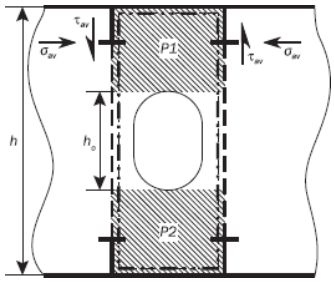
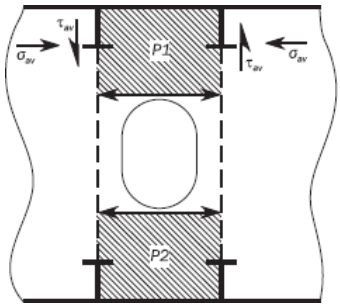
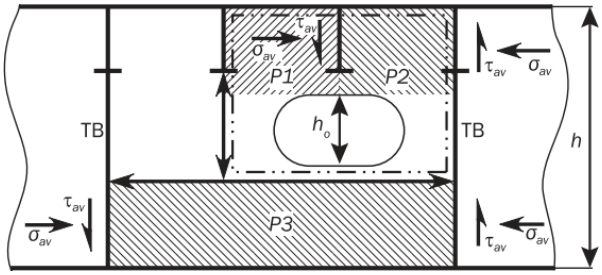


Figure 2 Web plate idealization

The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

Reduction factors **Table 6**

Configuration[1]	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
(a) Without edge reinforcements: [2] 	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 3 or case 6 in Table 3, with edge stress ratio: Ψ=1.0	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 18 or case 19 in Table 3	When case 17 of Table 3 is applicable: A common reduction factor is to be applied to areas *P1* and *P2* using case 17 in Table 3 with: $\tau_{av} = \tau_{av}$(web)
			When case 17 of Table 3 is not applicable: Separate reduction factors are to be applied to areas *P1* and *P2* using case 18 or case 19 in Table 3 with: $\tau_{av} = \tau_{av}$*(web)* $h/(h\text{-}h_0)$
(b) With edge reinforcements: 	Separate reduction factors are to be applied for areas *P*1 and *P*2 using C_x for case 1 or C_y for case 2 in Table 3 with stress ratio: Ψ=1.0	Separate reduction factors are to be applied for areas *P*1 and *P*2 using case 15 in Table 3.	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 15 in Table 3 with: $\tau_{av} = \tau_{av}$*(web)* $h/(h\text{-}h_0)$

Configuration[1]	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
(c) Example of hole in web:  		Panels *P*1 and *P*2 are to be evaluated in accordance with (a). Panel *P*3 is to be evaluated in accordance with (b).	

Where:
h : Height, in m, of the web of the primary supporting member in way of the opening.
h_0 : Height in m, of the opening measured in the depth of the web.
$\tau_{av}(web)$: Weighted average shear stress, in N/mm^2, over the web height h of the primary supporting member.
Note (1): Web panels to be considered for buckling in way of openings are shown shaded and numbered *P*1, *P*2, etc.
Note (2) : For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.

3 Buckling capacity of other structures

3.1 Struts, pillars and cross ties

3.1.1 Buckling utilisation factor

The buckling utilisation factor, η, for axially compressed struts, pillars and cross ties is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where:
σ_{av} : Average axial compressive stress in the member, in N/mm^2.
σ_{cr} : Minimum critical buckling stress, in N/mm^2, taken as:

$$\sigma_{cr} = \sigma_E \text{ for } \sigma_E \leq 0.5R_{eH_S}$$

$$\sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S} \text{ for } \sigma_E > 0.5R_{eH_S}$$

σ_E : Minimum elastic compressive buckling stress, in N/mm^2, according to [3.1.2] to [3.1.4].
R_{eH_S}: Specified minimum yield stress of the considered member, in N/mm^2. For built up members, the low-est specified minimum yield stress is to be used.

3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_{EC} in N/mm^2 of members subject to axial compression is to be taken as:

$$\sigma_{EC} = \pi^2 E f_{end} \frac{I}{A l_{pill}^2} 10^{-4}$$

where:
I : Net moment of inertia about the weakest axis of the cross section, in cm^4.
A : Net cross sectional area of the member, in cm^2.
l_{pill} : Length of the member, in m, taken as:

- For pillar and strut: unsupported length of the member
- For cross tie:
  - In centre tank: distance between the flanges of longitudinal stiffeners on the

starboard and port longitudinal bulkheads to which the cross tie's horizontal stringer is attached.

- In wing tank: distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stringer is attached, and the inner hull plating.

f_{end} : End constraint factor, taken as:

- For pillar and strut:
  - f_{end} = 1.0 where both ends are simply supported.
  - f_{end} = 2.0 where one end is simply supported and the other end is fixed.
  - f_{end} = 4.0 where both ends are fixed.
- For cross tie:
  - f_{end} = 2.0

A pillar end may be considered fixed when brackets of adequate size are fitted. Such brackets are to be sup- ported by structural members with greater bending stiffness than the pillar.

3.1.3 Elastic torsional buckling stress

The elastic torsional buckling stress, σ_{ET}, in N/mm^2, with respect to axial compression of members is to be taken as:

$$\sigma_{ET} = \frac{GI_{sv}}{I_{pol}} + \frac{\pi^2 f_{end} E c_{warp}}{I_{pol} l_{pill}^2} 10^{-4}$$

where:

I_{sv} : Net St. Venant's moment of inertia, in cm^4, see Table 7 for examples of cross sections.

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4

$$I_{pol} = I_y + I_z + A(y_0^2 + z_0^2)$$

c_{warp} : Warping constant, in cm6, see Table 7 for examples of cross sections.

l_{pill} : Length of the member, in m as defined in [3.1.2].

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for examples of cross sections.

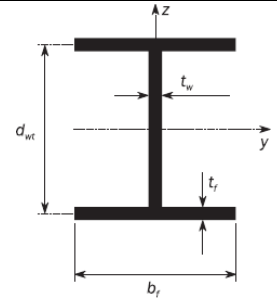
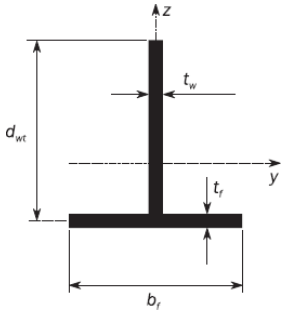
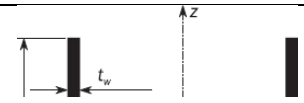
z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for exam- ples of cross sections.

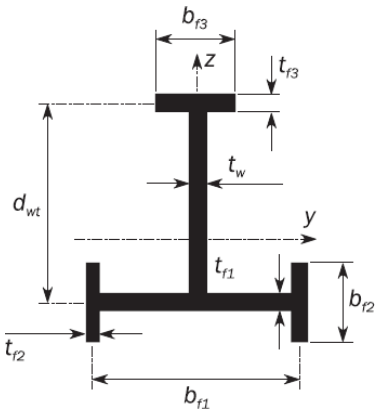
A : Net cross sectional area, in cm^2, as defined in [3.1.2]

I_y : Net moment of inertia about y axis, in cm^4.

I_z : Net moment of inertia about z axis, in cm^4.

Cross sectional properties **Table 7**

	$I_{sv} = \frac{1}{3}\left(2b_f t_f^3 + d_{wt} t_w^3\right)10^{-4}$	cm^4
	$c_{warp} = \frac{d_{wt}^2 b_f^3 t_f}{24} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(2b_f t_f^3 + d_{wt} t_w^3\right)10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = -\frac{0.5 d_{wt}^2 t_w}{d_{wt} t_w + b_f t_f} 10^{-1}$	cm
	$c_{warp} = \frac{b_f^3 t_f^3 + 4 d_{wt}^3 t_w^3}{144} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(b_{fu} t_f^3 + 2 d_{wt} t_w^3\right)10^{-4}$	cm^4

	$y_0 = 0$	cm
	$z_0 = -\frac{d_{wt}^2 t_w 10^{-1}}{2d_{wt}t_w + b_{fu}t_f} - \frac{0.5d_{wt}^2 t_w 10^{-1}}{d_{wt}t_w + b_{fu}t_f \ / \ 6}$	cm
	$c_{warp} = \frac{b_{fu}^2 d_{wt}^3 t_w (d_{wt}t_w + 2b_{fu}t_f)}{12(6d_{wt}t_w + b_{fu}t_f)} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(b_{f1}t_{f1}^3 + 2b_{f2}t_{f2}^3 + b_{f3}t_{f3}^3 + d_{wt}t_w^3\right)10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = z_s - \frac{(b_{f3}d_{wt}t_{f3} + 0.5d_{wt}^2 t_w)10^{-1}}{d_{wt}t_w + b_{f1}t_{f1} + 2b_{f2}t_{f2} + b_{f3}t_{f3}}$	cm
	$C_{warp} = \left(I_{f1}Z_s^2 + \frac{I_{f2}b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - Z_s\right)^2 \right)$	cm^6
	$I_{f1} = \left(\frac{\left(b_{f1} - t_{f2}\right)^3 t_{f1}}{12} + \frac{b_{f2}t_{f2}b_{f1}^2}{2} \right) 10^{-4}$	cm^4
	$I_{f2} = \frac{b_{f2}^3 t_{f2}}{12} 10^{-4}$	cm^4
	$I_{f3} = \frac{b_{f3}^3 t_{f3}}{12} 10^{-4}$	cm^4
	$z_s = \frac{I_{f3}d_{wt}}{I_{f1} + I_{f3}} 10^{-1}$	cm
Note1: All dimensions are in mm. Note2: Cross sectional properties are given for typical cross sections. Properties for other cross sections are to be determined by direct calculation.		

3.1.4 Elastic torsional/column buckling stress

For cross sections where the centroid and the shear centre do not coincide, the interaction between the tor- sional and column buckling mode is to be examined. The elastic torsional/column buckling stress, σ_{ETF}, with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[\left(\sigma_{EC} + \sigma_{ET}\right) - \sqrt{\left(\sigma_{EC} + \sigma_{ET}\right)^2 - 4\zeta\sigma_{EC}\sigma_{ET}} \right]$$

where:

ζ : Coefficient taken as:

$$\zeta = 1 - \frac{\left(y_0^2 + z_0^2\right)A}{I_{pol}}$$

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

A : Net cross sectional area, in cm^2, as defined in [3.1.2].

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4 as defined in [3.1.3].

σ_{EC} : Elastic column compressive buckling stress, as defined in [3.1.2].

σ_{ET} : Elastic torsional buckling stress, as defined in [3.1.3].

3.2 Corrugated bulkhead

3.2.1

The buckling utilisation factor of flange and web of corrugation of corrugated bulkheads is based on the combination of in plane stresses and shear stress.

The interaction curve of [2.2.1] is to be used with the following coefficients:

3.2.1 α=2

3.2.2 $\psi_x = \psi_y = 1$

Appendix 1 STRESS BASED REFERENCE STRESSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a : Length, in mm, of the longer side of the plate panel as defined in Sec 5.

b : Length, in mm, of the shorter side of the plate panel as defined in Sec 5.

A_i : Area, in mm^2, of the i-th plate element of the buckling panel.

n : Number of plate elements in the buckling panel.

σ_{xi} : Actual stress, in N/mm^2, at the centroid of the i-th plate element in x direction, applied along the shorter edge of the buckling panel.

σ_{yi} : Actual stress, in N/mm^2, at the centroid of the i-th plate element in y direction, applied along the longer edge of the buckling panel.

Ψ : Edge stress ratio as defined in Sec 5.

τ_i : Actual membrane shear stress, in N/mm^2, at the centroid of the i-th plate element of the buckling panel.

1 STRESS BASED METHOD

1.1 Introduction

1.1.1

This section provides a method to determine stress distribution along edges of the considered buckling panel by 2nd order polynomial curve, by linear distribution using least square method and by weighted average approach. This method is called Stress based Method.

The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Ch 8, Sec 4, [2.3.1].

1.2 Stress application

1.2.1 Regular panel

The reference stresses are to be taken as defined in [2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge a of a regular panel and
- This element centre is located at a distance in the panel local x direction not less than $a/4$ to at least one of the element centres in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [2.2] for an irregular panel.

1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [2.2].

2 REFERENCE STRESSES

2.1 Regular Panel

2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

- For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as 2nd order polynomial curve as:

  $\sigma_x = Cx^2 + Dx + E$

  The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor.

  $$\Pi = \sum_{i=1}^{n} A_i \left[\sigma_{xi} - \left(Cx^2 + Dx + E \right) \right]^2$$

  The unknown coefficients C, D and E must yield zero first derivatives, $\partial \Pi$ with respect

to C, D and E
respectively.

$$\frac{\partial \Pi}{\partial C} = 2\sum_{i=1}^{n} A_i x_i^2 \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

$$\frac{\partial \Pi}{\partial D} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

$$\frac{\partial \Pi}{\partial E} = 2\sum_{i=1}^{n} A_i \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

The unknown coefficients C, D and E can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)\mathrm{d}x = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)\mathrm{d}x = \left(a^2 - ab + \frac{b^2}{3} \right)C + \left(a - \frac{b}{2} \right)D + E$$

If $-D/2C < b/2$ or $-D/2\ C > a-b/2$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x\min}^{x\max} \sigma_x(x)\mathrm{d}x = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where:

$$x_{\min} = -\frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$\sigma_x = \max(\sigma_{x1};\ \sigma_{x2};\ \sigma_{x3})$

The edge stress ratio is to be taken as:

$\psi_x = 1$

- For overall stiffened panel buckling and stiffener buckling assessments, $\sigma_x(x)$ applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_1^n A_i \sigma_{xi}}{\sum_1^n A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

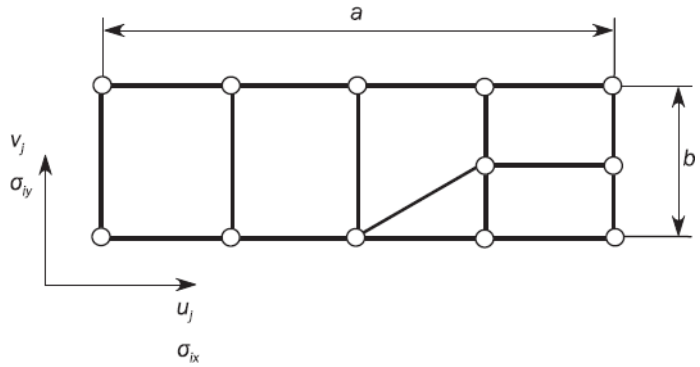


Figure 1 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$\sigma_y(x) = A+Bx$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i) \right]^2$$

The unknown coefficients A and B must yield zero first partial derivatives, $\partial\Pi$ with respect to A and B, respectively.

$$\frac{\partial \Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i) \right] = 0$$

$$\frac{\partial \Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{yi} - (A + Bx_i) \right] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$\begin{cases} A = \dfrac{\left(\sum_{i=1}^{n} A_i \sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2} \\ B = \dfrac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{iy}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2} \end{cases}$$

$$\sigma_y = \max(A,\ A+Ba)$$

$$\psi_y = \frac{\min(A,\ A+Ba)}{\max(A,\ A+Ba)} \quad \text{for } \sigma_y \geqslant 0$$

$$\Psi_y = 1 \quad \text{for } y < 0$$

2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{1}^{n} A_i \tau_i}{\sum_{1}^{n} A_i}$$

2.2 Irregular panel and curved panel

2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{1}^{n} A_i \sigma_{xi}}{\sum_{1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{1}^{n} A_i \sigma_{yi}}{\sum_{1}^{n} A_i}$$

$$\tau = \frac{\sum_{1}^{n} A_i \tau_i}{\sum_{1}^{n} A_i}$$

The edge stress ratios are to be taken as

Ψ_x =1

Ψ_y =1

Chapter 9 FATIGUE

Section 1 GENERAL CONSIDERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

T_{DF}: Design fatigue life, in year, specified by the designer, but not to be taken less than 25 years.

1 RULE APPLICATION FOR FATIGUE REQUIREMENTS

1.1 Scope

1.1.1 General

This chapter provides requirements applicable to ships having rule a freeboard length L_{LL} between 150 m and 500 m to evaluate fatigue strength of the ship's structural details considering an operation time in North Atlantic environment equal to the design fatigue life, T_{DF}.

1.1.2 Assessed area

Fatigue assessment is performed for structural details located in the ship's cargo hold region in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the toe of the weld and propagating into the plate.
- Fatigue cracks initiating from free edge of non-welded details.

1.1.3 Structural details to be assessed

The structural details required for fatigue assessment are given in Ch 9, Sec 2:

- Structural details to be checked are listed in:
  - Ch 9, Sec 2, [1] for simplified stress analysis according to Ch 9, Sec 4, or
  - Ch 9, Sec 2, [2] for finite element stress analysis according to Ch 9, Sec 5.
- Structural details to be checked by screening fatigue assessment are listed in Ch 9, Sec 2, Table 2.

Additional specific details may be requested to be checked on a case-by-case basis by the Society.

ISC 1.1.3a Where the fatigue strength of details other than those specified in Section 2 of this Chapter needs to be verified, fatigue assessment may be carried out in accordance with the requirements of this Chapter.

1.1.4 Detail design standard

Detail design standard given in Ch 9, Sec 6 provides welding requirement at critical structural details in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the weld toe into the base material.
- Fatigue cracks initiating from the weld root and propagating into the plate section under the weld.
- Fatigue cracks initiating from the weld root and propagating through the weld throat.
- Fatigue cracks initiating from surface irregularity or notch at the free edge into the base material.

1.1.5 Material

The fatigue assessment is applicable for steel material with specified minimum yield stress less than or equal to 390 N/mm^2. For steel with specified minimum yield stress value higher than 390 N/mm^2 and for steels with improved fatigue performance, the S-N curves to be used are considered by the Society on a case-by-case basis.

ISC 1.1.5a S-N curves in Chapter 9 of this PART or those in air and/or corrosive environment in IIW, HSE or ISO standards may be used, taking into account the applicability of the minimum yield stress. S-N curves obtained from testing may also be used and the probability of survival is not to be less than 97.7%.

ISC 1.1.5b Where S-N curves of other standards are used, relevant technical documents are to

be submitted as audit basis.
ISC 1.1.5c Where S-N curves obtained from testing are used, relevant testing reports are to be submitted as audit basis and the qualification proof of testing organization is also to be submitted.
ISC 1.1.5d Where S-N curves in corrosive environment are obtained from testing, the evidence demonstrating that the corrosive environment used in testing is equivalent to that of sea water is also to be submitted.

1.1.6 Wave loads
Fatigue assessment is based on quasi-static wave loads.

1.1.7 Loads other than wave loads
Fatigue induced by low cycle loads such as cargo variations or impact loads such as sloshing in partially filled tanks which may induce fatigue damage is disregarded in this chapter.

2 DEFINITION

2.1 Hot spots

2.1.1
Hot spots are locations in the structure where fatigue cracks may initiate due to the combined effect of nominal structural stress fluctuation and stress raising effects due to the weld geometry or similar effects due to notch in the base material.
Hot spots may be located at:

2.1.1 Weld toe.

2.1.2 Weld root of partial penetration or fillet weld.

2.1.3 Base material at free edge of plate.

2.2 Nominal stress

2.2.1
Nominal stress is the stress in a structural component taking into account macro-geometric effect but disregarding the stress concentration due to structural discontinuities and the presence of welds. Nominal stress is to be obtained either using coarse or fine mesh FE analysis, as required in Ch 9, Sec 5 or using analytical calculation based on beam theory, as required in Ch 9, Sec 4.

2.3 Hot spot stress

2.3.1
Hot spot stress is the stress at the weld toe taking into account the stress concentration due to structural discontinuities and presence of welded attachments but disregarding the non-linear stress peak caused by the notch at the weld toe. The hot spot stresses to be considered correspond to the two principal stresses on the surface plating at the weld toe. The first principal stress acts within ±45°, perpendicular to the weld and the second principal stress acts outside ±45°.
The hot spot stress is to be obtained by multiplying the nominal stress by a Stress Concentration Factor (SCF), according to Ch 9, Sec 4, [5] or directly by a very fine mesh FE analysis, according to Ch 9, Sec 5, [3] and Ch 9, Sec 5, [4].

2.4 Local stress at free edge

2.4.1
Local stress at free edge is the stress at the plate free edge derived using finite element analysis according to Ch 9, Sec 5, [3.2].

2.5 Fatigue stress

2.5.1
Fatigue stress is the stress relevant for fatigue assessment purpose,i.e.:

2.5.1 Maximum of the two principal hot spot stress for weld toe with the mean stress effect and thickness effect corrections.

2.5.2 Local stress at free edge with corrections due to the base material surface finishing, mean stress effect, thickness effect and material strength.

3 ASSUMPTIONS

3.1 General

3.1.1

The following assumptions are made in the fatigue assessment:

a) A linear cumulative damage model, i.e. Palmgren-Miner's Rule, given in Ch 9, Sec 3, [5], has been used in connection with the design S-N curves, given in Ch 9, Sec 3, [4].
b) Design fatigue life, T_{DF}, is taken not less than 25 years.
c) Rule quasi-static wave induced loads are based on North Atlantic wave environment. They are determined at 10^{-2} probability level of exceedance by the Equivalent Design Wave (EDW) concept.
d) Net thickness t_{n50} approach is used, according to [5].
e) Type of stress used for crack initiating at the weld toe is the hot spot stress. Type of stress used for crack initiating at free edge of non-welded details is local stress at free edge.
f) Fatigue stress range $\Delta\sigma_{FS}$ may be calculated by simplified stress analysis or by finite element stress analysis for details with more complex geometry.
g) Long term distribution of stress range of a structural detail is assumed to follow a two-parameter Weibull distribution. Weibull shape parameter is equal to 1 and the fatigue stress range $\Delta\sigma_{FS}$ is given at the reference probability level of exceedance equal to 10^{-2}.
h) The acceptance criteria for fatigue checking are the total fatigue damage D to be less than 1 for the design fatigue life, as required in Ch 9, Sec 3, [2].

4 METHODOLOGY

4.1 Principles

4.1.1 General

Appropriate fatigue strength of structural details is ensured by use of:

- Detail design standards given in Ch 9, Sec 6, providing specific design requirements.
- Fatigue strength assessment by fatigue life calculation, based on three different methods for hot spot stress calculation: simplified stress analysis, very fine mesh finite element stress analysis and fatigue screening assessment.

4.2 Simplified stress analysis

4.2.1

Procedure based on simplified stress analysis, required in Ch 9, Sec 4, is used to determine the hot spot stress at weld toe of longitudinal stiffener end connections, given in Ch 9, Sec 2, [1.1].

Nominal stresses are calculated by using analytical method based on beam theory according to Ch 9, Sec 4, [3] and Ch 9, Sec 4, [4]. Hot spot stresses are obtained by multiplying nominal stresses by stress concentration factors (SCF) of the considered detail according to Ch 9, Sec 4, [5.2].

4.3 Finite element stress analysis

4.3.1

Procedure based on finite element stress analysis, required in Ch 9, Sec 5, is used to determine hot spot stress at weld toe of specified structural details, from very fine mesh models.

The hot spot stress is generally highly dependent on the finite element model used for representing the structure.

General procedure for the calculation of hot spot stress at weld toe for any welded details except for web stiffened cruciform joints is given in Ch 9, Sec 5, [3.1]. Procedure for the calculation of hot spot stress at the flange connections for web stiffened cruciform joints is given in Ch 9, Sec 5, [4]. Calculation of local stress for non-welded area is provided in Ch 9, Sec 5, [3.2].

A list of details for which the fatigue assessment is to be made through a compulsory very fine mesh finite element analysis or through the compliance with the design standard given in Ch 9, Sec 6 if a very fine mesh finite element analysis is omitted, is given respectively in Ch 9, Sec 2, Table 1 and Ch 9, Sec 2, Table 3.

4.4 Fatigue screening assessment

4.4.1

A fatigue screening procedure is used to assess the fatigue strength of specified structural details, given in Ch 9, Sec 2, [2.1.3]. The screening procedure is based on screening hot spot stress at

weld toe of specified structural details determined by multiplying the stresses obtained from a local fine mesh finite element model, required in Ch 7, Sec 3, by stress magnification factor of the considered detail, given in Ch 9, Sec 5, Table 2.

4.5 Fatigue design standards

4.5.1

Detail design standards given in Ch 9, Sec 6 are provided to ensure improved fatigue performance of critical structural details. Alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.

5 CORROSION MODEL

5.1 Net thickness

5.1.1 General

The fatigue assessment should be performed based on net thicknesses according to Ch 3, Sec 2.

5.1.2 Stress correction

The hull girder stresses for simplified stress analysis and stresses calculated by FE analysis are to be corrected by multiplying the calculated stress by f_c, correction factor taken as:

f_c =0.95

6 LOADING CONDITIONS

6.1 Description

6.1.1

Fatigue analyses are to be carried out for representative loading conditions according to the intended ship's operation as given in [6.2] and [6.3].

6.2 Loading conditions for oil tankers

6.2.1

The loading conditions to be considered for oil tankers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined in Table 1. The standard loading conditions for fatigue assessment of oil tankers are provided in Ch 4, Sec 8, [5.1].

Fraction of time in each loading condition for oil tanker **Table 1**

Loading conditions	$\alpha_{(j)}$
Full Load condition (Homogeneous)	0.5
Normal ballast condition	0.5

6.3 Loading conditions for bulk carriers

6.3.1

The loading conditions to be considered for bulk carriers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined respectively in Table 2 and Table 3 depending on the ship's type (BC-A, BC-B, BC-C). The standard loading conditions for fatigue assessment of bulk carriers are provided in Ch4, Sec 8, [5.2].

Loading conditions for bulk carriers **Table 2**

Ship type	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	X	X	X	X
BC-B	X	-	X	X
BC-C	X	-	X	X

7 LOAD CASES

7.1 Assumptions

7.1.1

The load cases to be considered for fatigue assessment are given in Ch 4, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 4, Sec 7, Table 3.

For each loading condition defined in [6], all fatigue load cases are to be considered to generate the combination of dynamic loads for fatigue assessment

7.1.2 Predominant load case

The predominant load case for each loading condition (j) is defined as load case where the fatigue stress range for the critical location is the maximum among all fatigue load cases.

Fraction of time for each loading condition of bulk carriers **Table 3**

Ship length	Loading conditions	$\alpha_{(j)}$	
		BC-A	BC-B, BC-C
L < 200 m	Homogeneous	0.60	0.70
	Alternate	0.10	-
	Normal ballast(1)	0.15	0.05
	Heavy ballast(1)	0.15	0.25
$L \geqslant$ 200 m	Homogeneous	0.25	0.50
	Alternate	0.25	-
	Normal ballast	0.20	0.20
	Heavy ballast	0.30	0.30

(1) For BC-B and BC-C without heavy ballast cargo hold, fraction of time $\alpha_{(j)}$ for normal ballast is 0.30 and for heavy ballast 0.

Section 2 STRUCTURAL DETAILS TO BE ASSESSED

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

EA : Empty cargo hold in alternate loading condition.

FA : Full cargo hold in alternate loading condition.

1 SIMPLIFIED STRESS ANALYSIS

1.1 Structural details to be assessed

1.1.1

Critical structural details to be checked over the full extent of the cargo region for fatigue assessment by simplified stress analysis according to Ch 9, Sec 1 are:

- End connections of longitudinal stiffeners to transverse bulkheads, including swash bulkheads,
- End connections of longitudinal stiffeners to floors and web frames.

2 FINITE ELEMENT ANALYSIS

2.1 Structural details to be assessed

2.1.1 General

Critical structural details to be checked for fatigue by finite element analysis according to Ch 9, Sec 5 are given in [2.1.2] to [2.1.4].

Table 4 to Table 19 give the list of hot spots for structural details.

ISC 2.1.1a The requirements in Table 16 apply to the hot spots corresponding to the 6th item in Table 3 of Section 2, Chapter 9. Fatigue assessment of the following hot spots is to be carried out, see Figure ISC 2.1.1a.

(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure ISC 2.1.1a;

(2) *intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure ISC 2.1.1a;*

(3) *intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure ISC 2.1.1a;*

(4) *intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure ISC 2.1.1a (where hot spots 10 and 11 are located near the middle point of side length);*

(5) *intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure ISC 2.1.1a.*

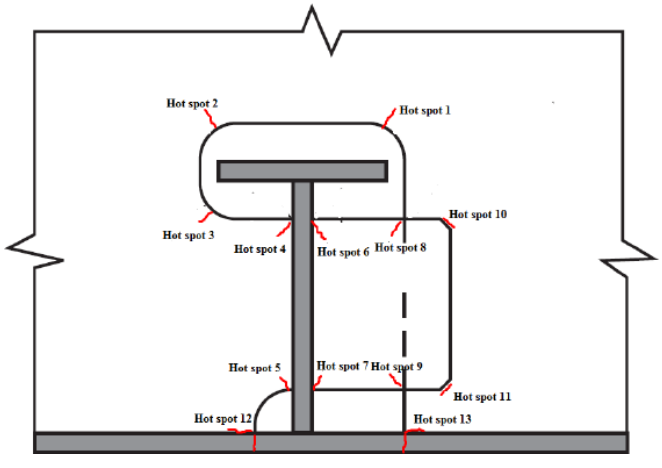


Figure ISC 2.1.1a Critical Hot Spot

ISC 2.1.1b The general requirements for FE modeling of Table 16 are given in 2.1.1 to 2.1.7 of Section 5.

ISC 2.1.1c The FE modeling requirements in way of the cut-out in Table 16 are given in ISC 2.2.1a of Section 6. In way of hot spots 10 and 11, the number of mesh along the side length is not

to be less than 4.
ISC 2.1.1d The fatigue assessment method in Table 16 is given in Sections 1 and 3.

2.1.2 Details to be checked by very fine mesh analysis

Critical structural details to be assessed for fatigue by very fine mesh analysis according to Ch 9, Sec 5, [1] to Ch 9, Sec 5, [4] are provided in Table 1, irrespective of their compliance with the design standard given in Ch 9, Sec 6.

2.1.3 Details to be checked by screening fatigue assessment

The structural details listed in Table 2 for which FE fine mesh models have been analysed according to yielding requirements given in Ch 7, Sec 3 are to be assessed using the screening fatigue procedure as given in Ch 9, Sec 5, [6]. or to be assessed by very fine mesh analysis according to Ch 9, Sec 5, [1] to [4].

2.1.4 Details in accordance with detail design standard

Table 3 gives critical structural details for which fatigue assessment by very fine mesh analysis can be omitted if their design is in accordance with detail design standard given in Ch 9, Sec 6.

Structural details to be assessed by very fine mesh analysis **Table 1**

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Welded lower hopper knuckle connection (intersection of hopper sloping plate, inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
2	Radiused lower hopper knuckle connection (intersection of knuckled inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
3	Welded upper knuckle connection (intersection of hopper sloping plate, inner hull longitudinal bulkhead, transverse web and side stringer) where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location. (1)	One cargo tank (4)	Ballast hold of double side bulk carrier
4	Connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders. (2) (3)	One cargo tank (4)	Ballast hold
5	Upper side frame bracket toe in case of flat bottom of top wing tank. (1)	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Deck plating and longitudinal hatch coaming end bracket toe.	N/A	Two aftermost holds, midship hold and two foremost holds

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth location of the largest hold.
(4) Cargo hold located closest to the midship.

Structural details for screening fatigue assessment **Table 2**

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Bracket toe of transverse web frame	Applicable (1)	N/A
2	Toe of horizontal stringer	Applicable (1)	N/A

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
3	Lower hopper knuckle connection in EA hold (2) and in FA hold (2) not assigned as a ballast hold	N/A	Applicable (1)
4	Connections of transverse bulkhead lower stool to inner bottom in EA hold (2) and in FA hold (2) where the ballast hold is not assigned to the ship	N/A	Applicable (1)

(1) For details assessed by fine mesh analysis according to Ch 7, Sec 3, [3.2].
(2) Cargo hold located closest to the midship.

Structural details to be assessed by very fine mesh analysis if not designed in accordance with detail design standard Table 3

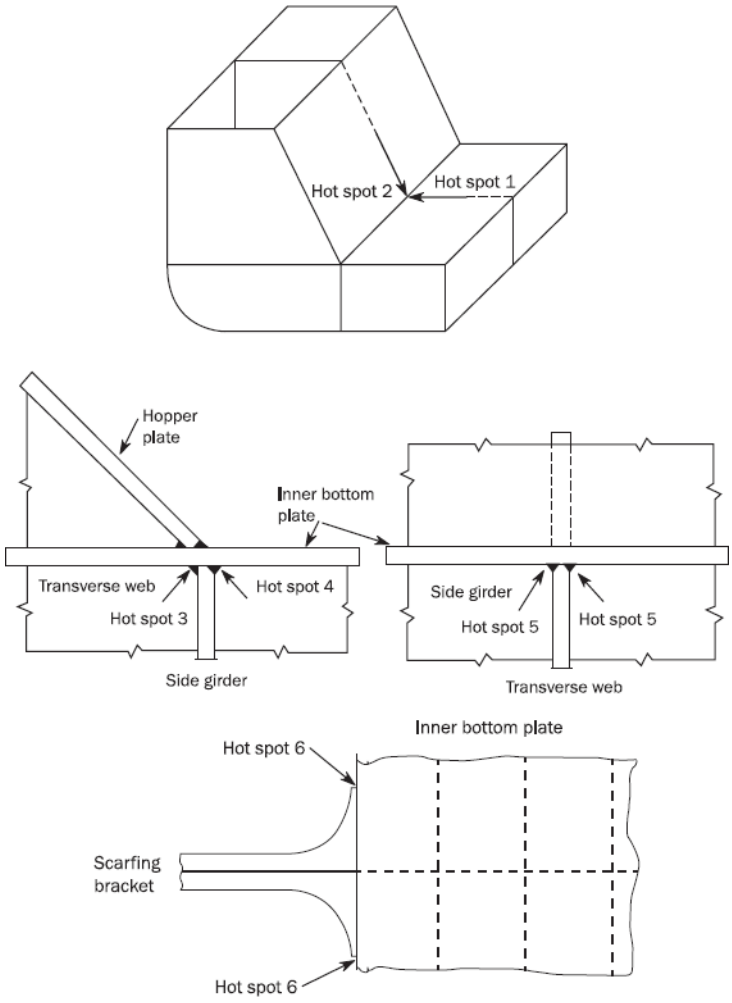
No	Critical detail	Corresponding detail design standard	Applicability	
			Oil tanker	Bulk carrier
1	Radiused upper hopper knuckle connection (intersection of knuckled inner side plate, side girder and transverse web) at the most critical frame location. (1)	Ch 9, Sec 6, [4]	One cargo tank (4)	Ballast hold of double side bulk carrier
2	Corrugations of bulkheads to lower stool or inner bottom plating connection. (2) (3)	Ch 9, Sec 6, [6] and Ch 9, Sec 6, [7]	One cargo tank (4)	Ballast hold
3	Corrugations of transverse bulkheads to upper stool. (2) (3)	Ch 9, Sec 6, [6]	N/A	Ballast hold
4	Cruciform heel connections between side stringers in double side and transverse bulkhead horizontal stringers, for the stringer closest to the mid depth and for the uppermost one.	Ch 9, Sec 6, [5]	One cargo tank	N/A
5	Lower and upper side frame bracket toes at the most critical frame position. (1)	Ch 9, Sec 6, [8]	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Cut out for longitudinal stiffeners in web-frame without web stiffener connection.	Ch 9, Sec 6, [2.1]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold
7	Scallops in way of block joints on strength deck close to mid hold (and down to 0.1D from deck corner).	Ch 9, Sec 6, [3]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth or length location of the largest hold in the considered transverse section or longitudinal section.
(4) Cargo hold located closest to the midship.

Hot spots for welded lower hopper knuckle connection Table 4

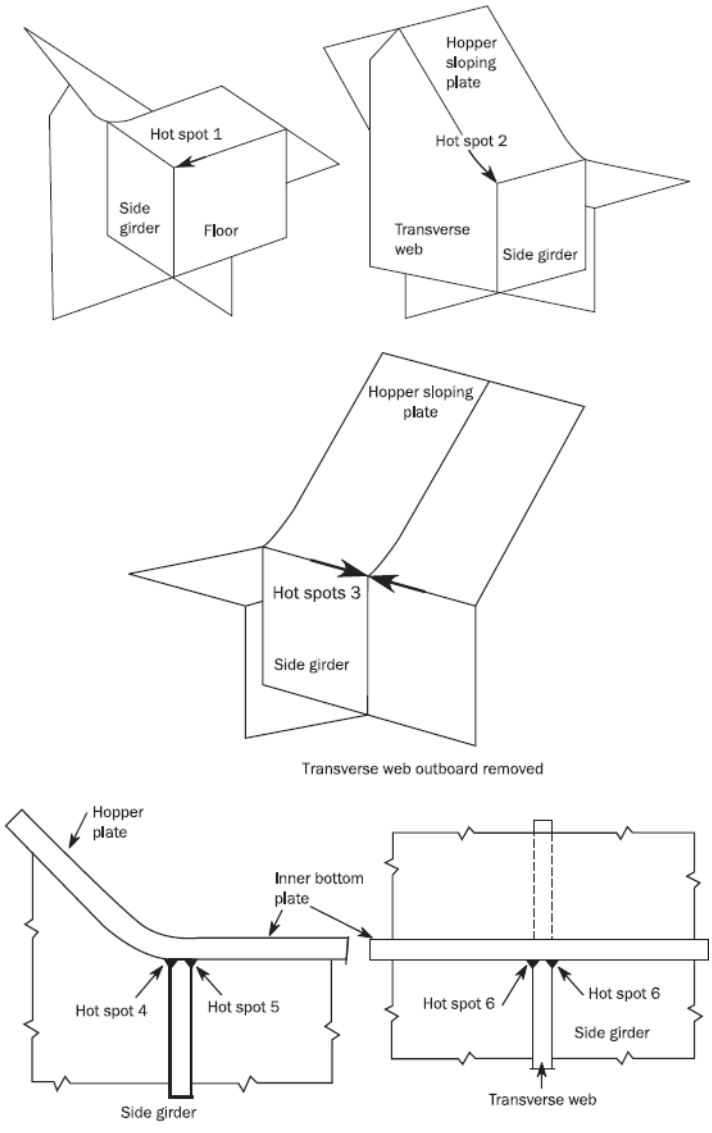
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo tank side Hot spot 2: Hopper sloping plate, on cargo tank side	Ch 9, Sec 5, [4.2]

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 3: Hopper web, outboard of side girder Hot spot 4: Double bottom floor, inboard the side girder Hot spot 5: Side girder	Ch 9, Sec 5, [4.3]
Hot spot 6: Scarfing bracket to the inner bottom plate	Ch 9, Sec 5, [3.1], type '*b*'



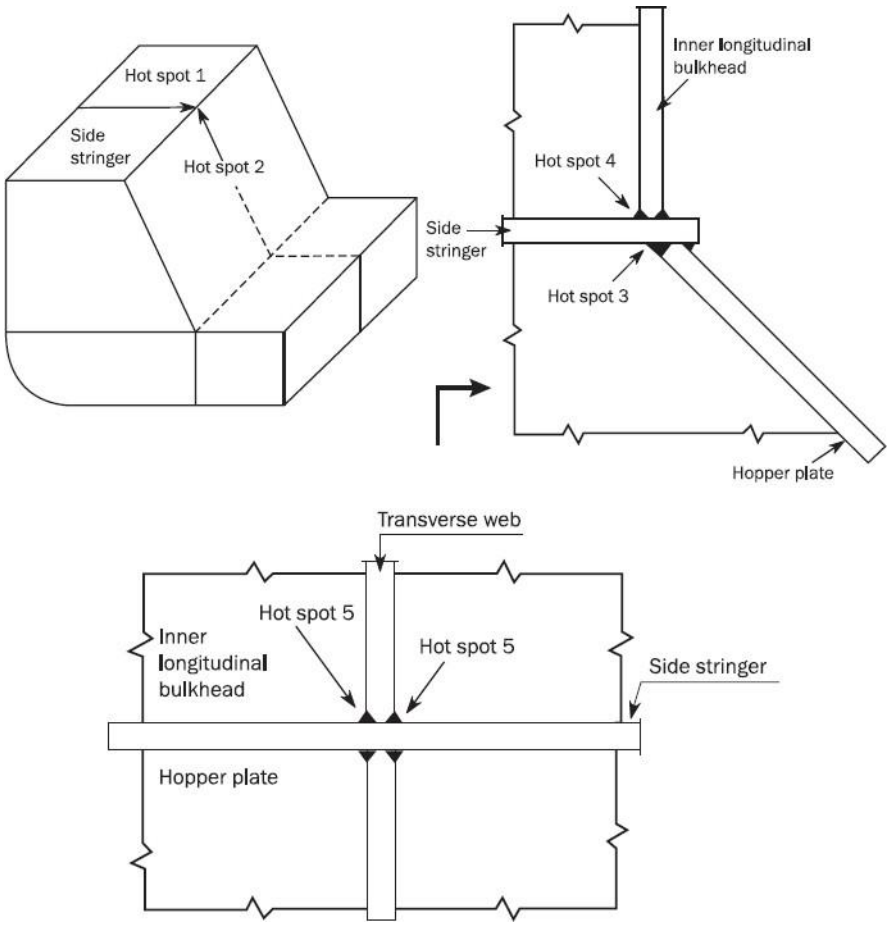
Hot spots for radiused lower hopper knuckle connection **Table 5**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate on ballast tank side, inboard of the side girder Hot spot 2: Radiused hopper sloping plate on ballast tank side outboard of the side girder Hot spot 3: Radiused hopper sloping plate on ballast tank side, outboard of the side girder, towards transverse web Hot spot 4: Hopper web, outboard of side girder Hot spot 5: Double bottom floor, inboard of the side girder Hot spot 6: Side girder	Ch 9, Sec 5, [3.3]



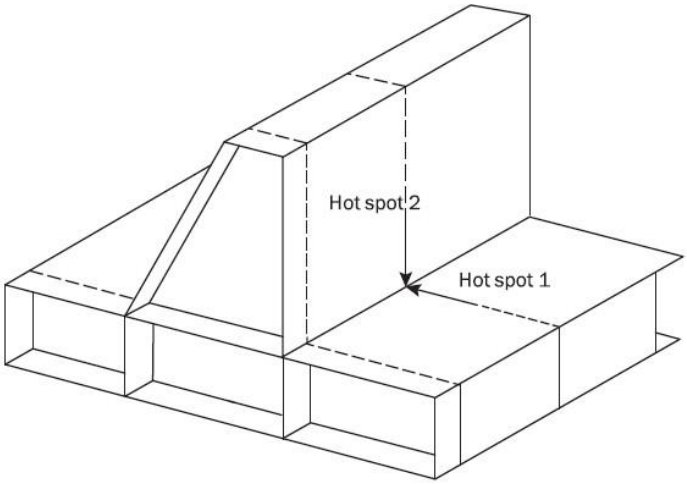
Hot spots for welded upper knuckle connection **Table 6**

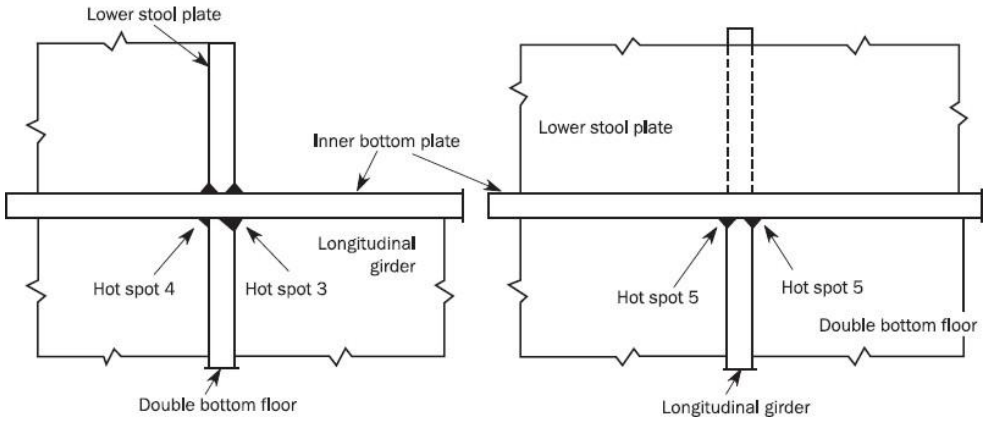
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Side stringer on ballast tank side Hot spot 2: Hopper sloping plate, on ballast tank side	Ch 9, Sec 5, [4.2]
Hot spot 3: Transverse web, below stringer. Hot spot 4: Transverse side web, above stringer Hot spot 5: Inner hull longitudinal bulkhead on ballast tank side	Ch 9, Sec 5, [4.3]



Hot spots for connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders **Table 7**

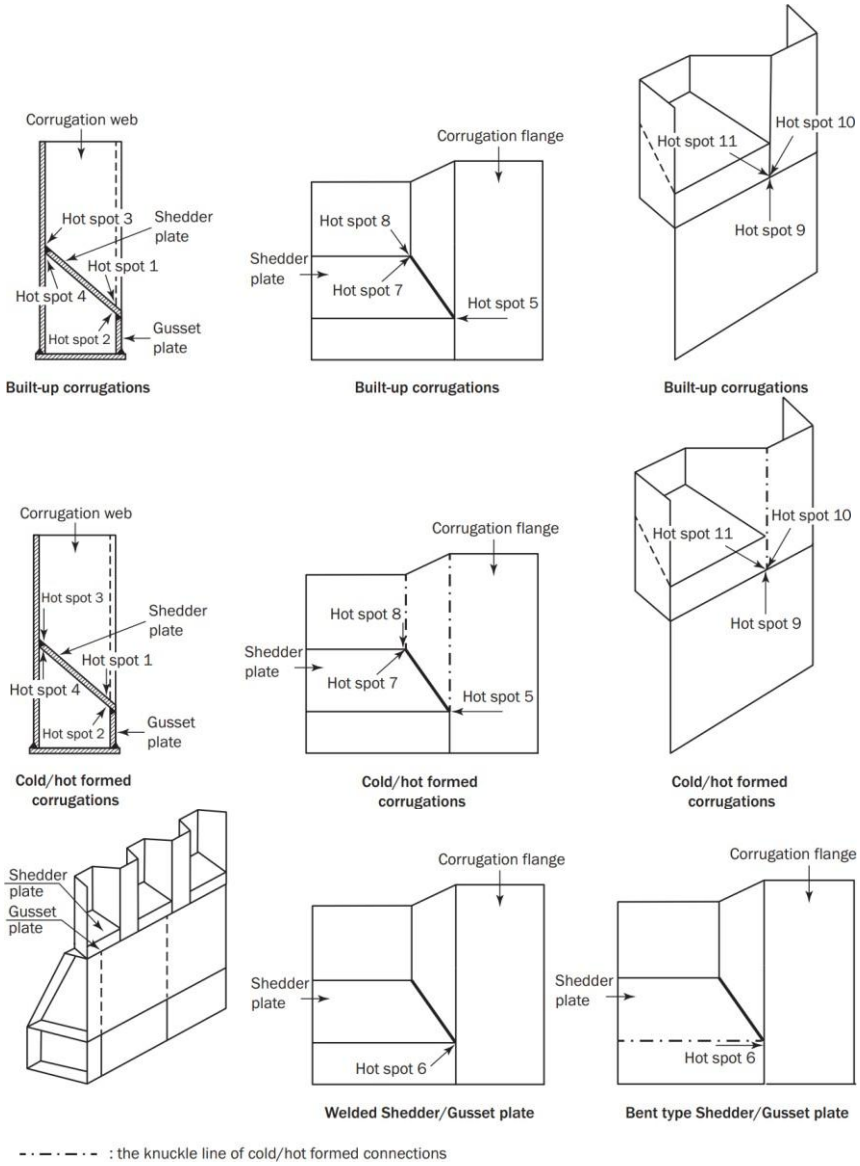
Hot spot ocation	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo hold side Hot spot 2: Stool sloping plate, on cargo hold side	Ch 9, Sec 5, [4.2]
Hot spot 3: Longitudinal girder, under hold, to supporting floor in line with stool plate Hot spot 4: Longitudinal girder, under stool space to supporting floor in line with stool plate Hot spot 5: Double bottom supporting floor in line with stool plate	Ch 9, Sec 5, [4.3]



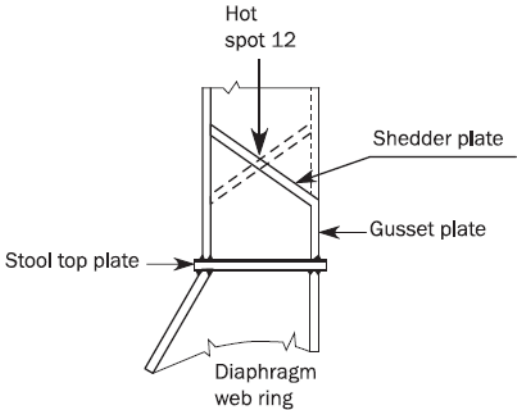
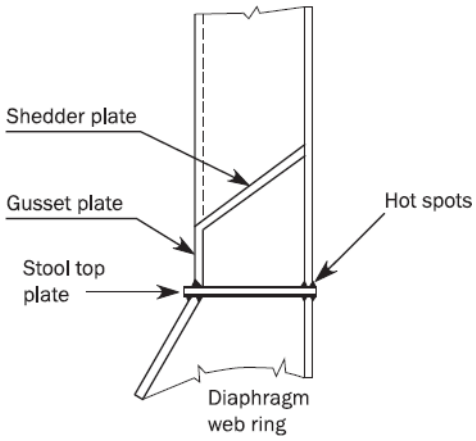


Hot spots for corrugated bulkhead to lower stool connection **Table 8**

Hot spot location		Procedure for calculation of hot spot stress	
		Cold/hot formed corrugations (Bent type)	Built-up corrugations (welded)
Hot spots 1 and 3: Corrugation web above shedder plate Hot spot 4: Corrugation web below shedder plate Hot spot 8: Corrugation flange		Ch 9, Sec 5, [3.1], type 'a'	Ch 9, Sec 5, [4.3]
Hot spot 2: Corrugation web below shedder plate Hot spot 7: Shedder plate Hot spot 10: Corrugation corner to stool top plate Hot spot 11: Gusset plate in way of corrugation corner		Ch 9, Sec 5, [4.3]	
Hot spot 5: Corrugation flange Hot spot 9: Lower stool plate to stool top plate		Ch 9, Sec 5 [3.1], type 'a'	
Hot spot 6: Gusset plate in case of:	welded gusset plate/shedder plate	Ch 9, Sec 5, [4.3]	
	bent type gusset plate/shedder plate	Ch 9, Sec 5, [3.1], type 'a'	



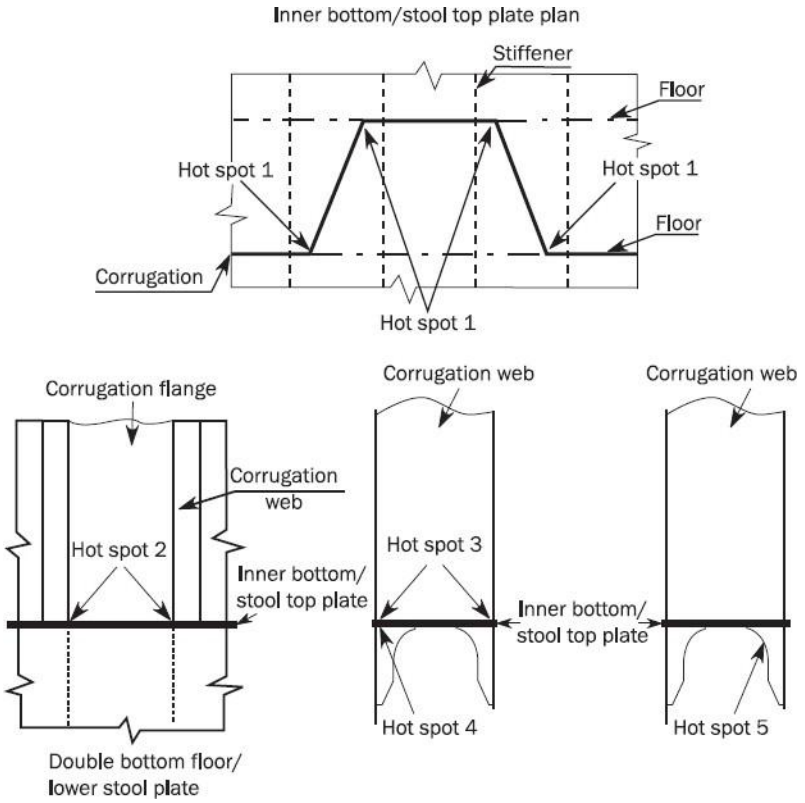
Hot spots for corrugated bulkhead to lower stool - Intersecting shedder plates and single sided shedder plate **Table 9**

Hot spot location	Procedure for calculation of hot spot stress
Intersecting shedder plates	
Hot spot 12: Intersection of shedder plates	Ch 9, Sec 5, [3.1], type '*a*'
	
Single sided shedder plate	
Welded connection of web and flange of corrugation to lower stool top For details of hot spots see Table 10, hot spots 1-3 If supported brackets are fitted, see Table 10 for hot spots 4	Ch 9, Sec 5, [3.1], type '*a*'
	

Hot spots for corrugated bulkhead to lower stool or inner bottom plating connection

Table 10

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1 : Inner bottom/lower stool top Hot spot 2: Corner of corrugation flange in way of inner bottom/lower stool top Hot spot 3: Corner of corrugation web in way of inner bottom/lower stool top Hot spot 4: Inner bottom/lower stool top in way of brackets supporting corrugation web	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Edge of supporting brackets	Ch 9, Sec 5, [3.2].



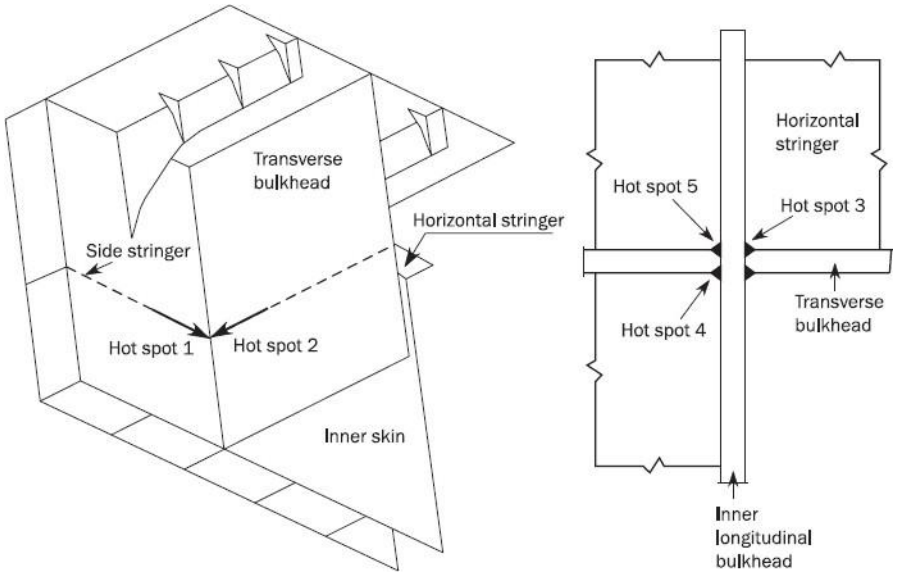
Hot spots for connections of corrugated longitudinal bulkhead to lower stool top Table 11

Hot spot location	Procedure for calculationof hot spot stress
See Table 9	Ch 9, Sec 5, [3.1], type '*a*'

Hot spots for connections of corrugated transverse bulkhead to upper stool bottom plate or to deck plate for tanker design without top stool Table 12

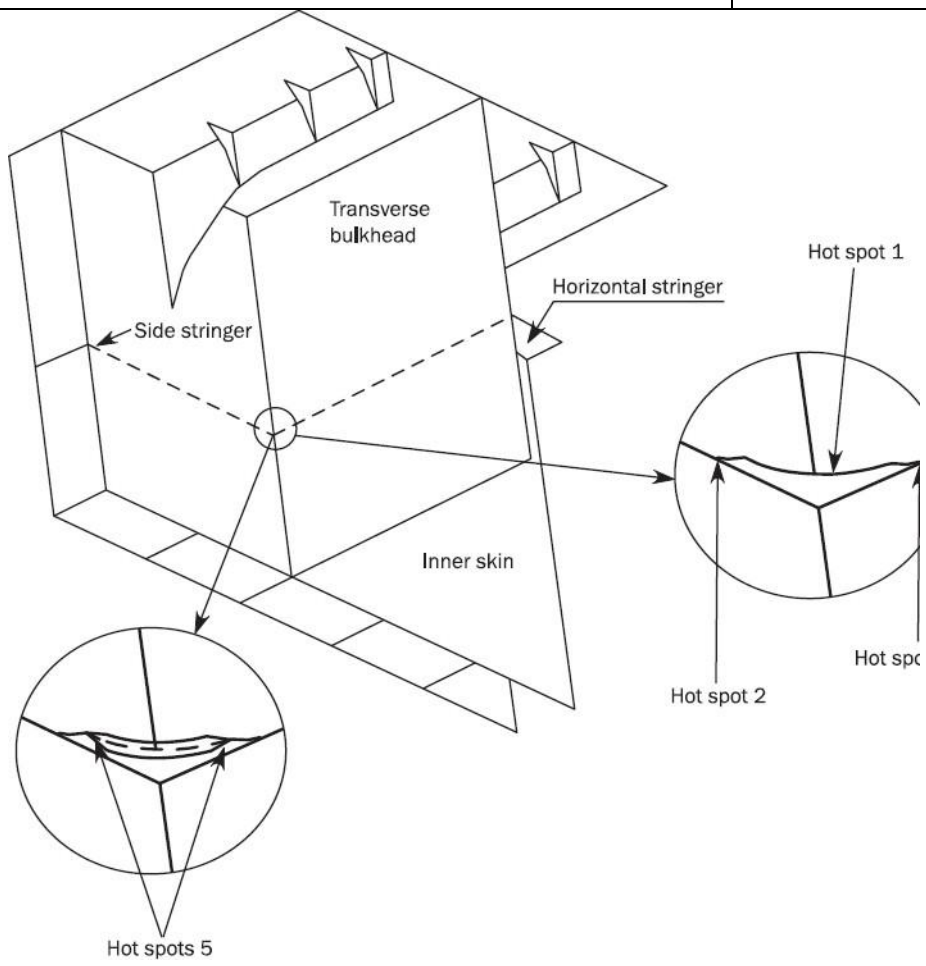
Hot spot location	Procedure for calculation of hot spot stress
See Table 8 and Table 9 Additional bending stresses in the deck stiffeners in way of corrugation flange induced by the bulkhead need to be considered	

Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer without backing bracket at stringer heel **Table 13**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner hull longitudinal bulkhead plate on cargo tank side connection to plane side of transverse bulkhead (i.e. opposite side to stiffening) at heel of transverse bulkhead horizontal stringer Hot spot 2: Transverse bulkhead plate on plane side (i.e. opposite stiffening) at heel of transverse bulkhead horizontal stringer	Ch 9, Sec 5, [4.2]
Hot spot 3: Heel of transverse bulkhead horizontal stringer Hot spot 4: Side stringer in double side diagonally opposite horizontal stringer Hot spot 5: Side stringer in double side in line with horizontal stringer	Ch 9, Sec 5, [4.3]
	

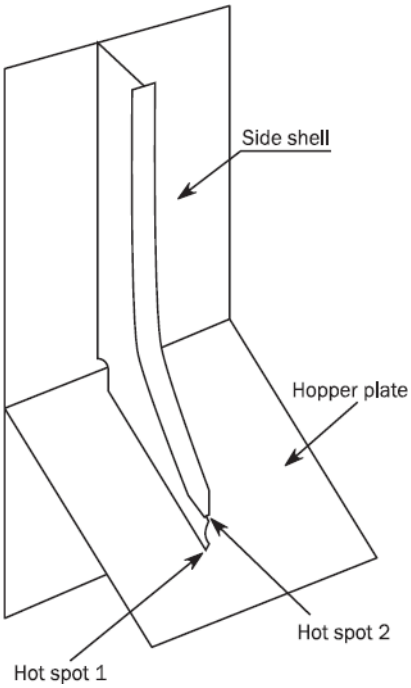
Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer, with backing bracket at stringer heel **Table 14**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Bracket edge where a face plate is not fitted to the bracket Hot spot 4: Radius of bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Inner longitudinal bulkhead at bracket toe Hot spot 3: Transverse bulkhead at bracket toe Hot spot 6: Side stringer, in way of bracket toe Hot spot 7: Horizontal stringer in way of bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'



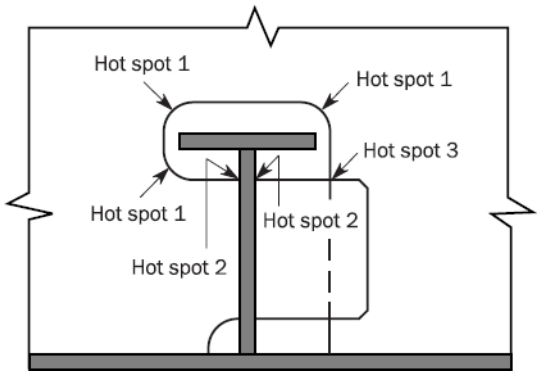
Hot spots for lower side frame bracket toe **Table 15**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hopper sloping plate in way of hold frame toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 2: Hold frame toe in way of face plate termination	Ch 9, Sec 5, [3.1], type '*b*'

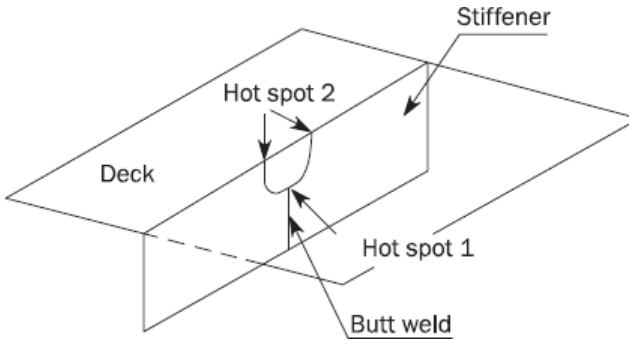


Hot spots for connection of longitudinal stiffener and transverse web including cut-outs and lug plates **Table 16**

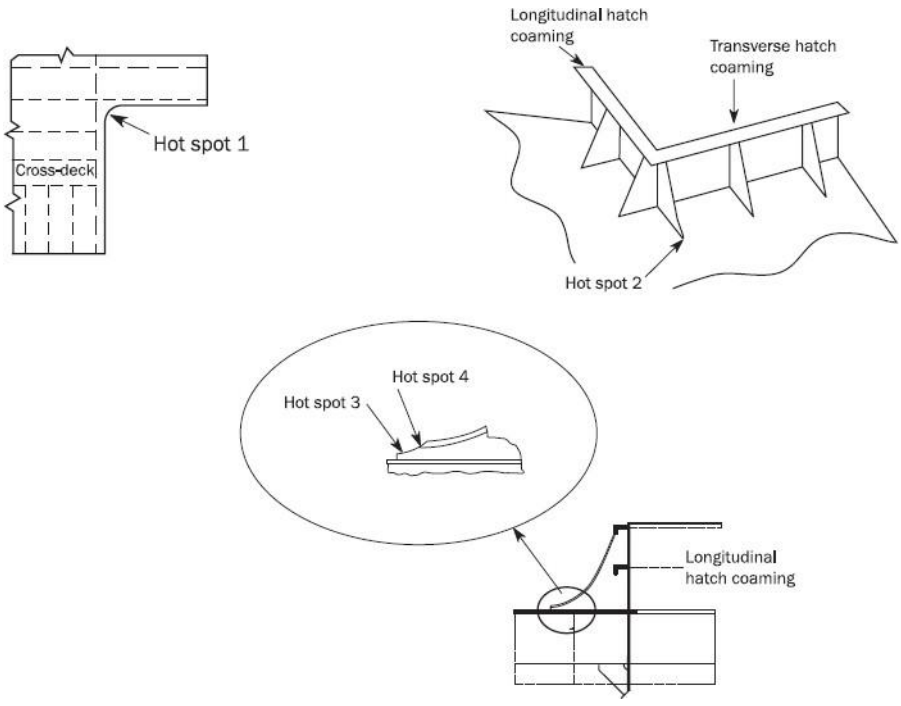
Hot spot location	Procedure for calculation of hot spot stress
The critical hot spot has to be decided for each design in agreement with the Society. Typically the following three hot spot types are to be considered:	
Hot spot 1: Corners of the cut-out edge	Ch 9, Sec 5, [3.2].
Hot spot 2: Connection of transverse web/lug-plate to longitudinal stiffener web in way of slot Hot spot 3: Overlapping connection between transverse web and lug plate	Ch 9, Sec 5, [3.1], type '*b*'



Hot spots for scallops in way of block connections joints at deck Table 17

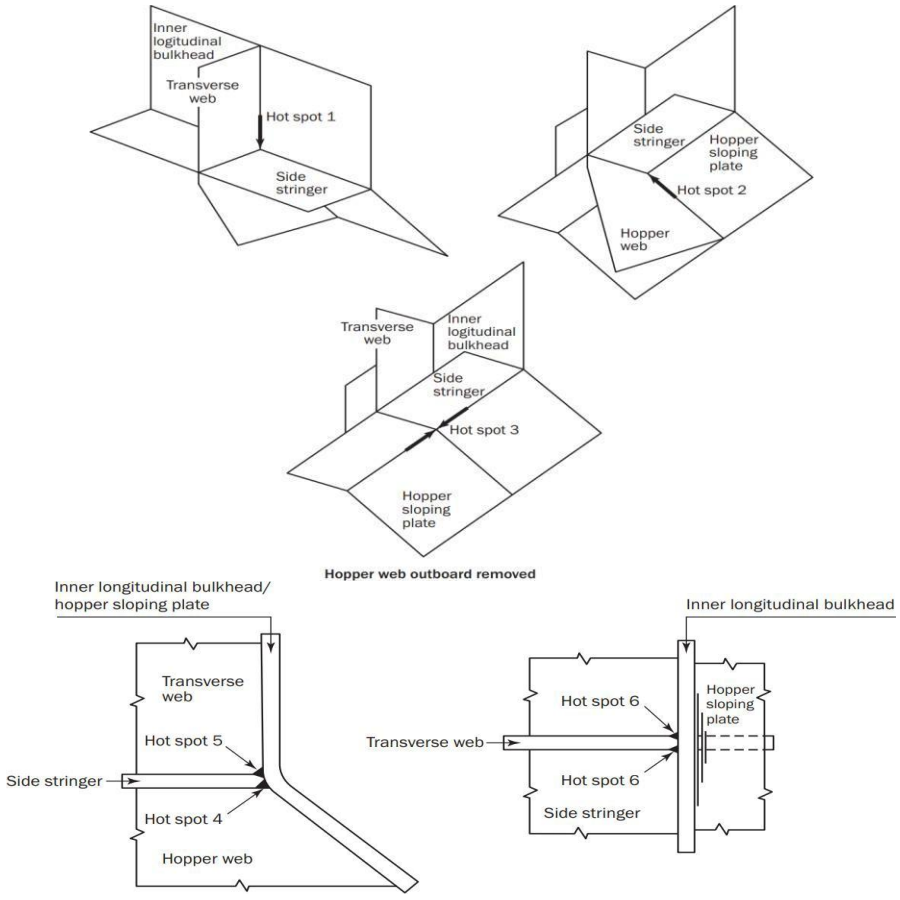
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Butt weld in longitudinal stiffener web in way of scallop. Hot spot 2: Deck plate in way of scallop.	Ch 9, Sec 5, [3.1], type '*a*'
	

Hot spots for deck plating and longitudinal hatch coaming end bracket toe Table 18

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hatch corner radiused edge Hot spot 3: Radius of hatch coaming bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Deck plating in way of hatch coaming bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 4: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'
	

Hot spots for radiused upper hopper knuckle connection **Table 19**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner longitudinal bulkhead plate on ballast tank side, above side stringer Hot spot 2: Radiused hopper sloping plate on ballast tank side, below side stringer Hot spot 3: Radiused hopper sloping plate on ballast tank side, below side stringer, towards hopper web Hot spot 4: Hopper web, below side stringer Hot spot 5: Transverse web, above side stringer Hot spot 6: Side stringer, to transverse web	Ch 9, Sec 5, [3.3]



Section 3 FATIGUE EVALUATION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3].

'*i1*' denotes load case: HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S.

'*i2*' denotes load case: HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:

Full load or normal ballast for oil tankers as defined in Ch 9, Sec 1, [6.2].

Full load homogeneous, full load alternate, normal ballast or heavy ballast for bulk carriers as defined in Ch 9, Sec 1, [6.3].

T_C : Time in corrosive environment, in years, according to Table 5.

T_D : Design life, in years, to be taken as 25 years.

T_{DF} : Design fatigue life, in year, as defined in Ch 9, Sec 1.

T_F : Fatigue life, in year, calculated according to [5].

m :Inverse slope of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

The inverse slope for S-N curves in-air environment changes from m to m+2 at $N = 10^7$ cycles.

n_{LC} : Number of applicable loading conditions, as defined in Ch 9, Sec 1, [6.2] and Ch 9, Sec 1, [6.3].

fc : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{thick} : Correction factor for plate thickness effect given in [3.3].

$f_{mean,\ i(j)}$: Correction factor for mean stress effect given in [3.2].

1 FATIGUE ANALYSIS METHODOLOGY

1.1 Cumulative damage

1.1.1

The fatigue assessment of the structure is based on the application of the Palmgren-Miner cumulative damage D taken as:

$$D = \sum_{i-1}^{n_{tot}} \frac{n_i}{N_i}$$

where:

n_i : Number of cycles at stress range $\Delta\sigma_i$.

N_i : Number of cycles to failure at stress range $\Delta\sigma_i$.

n_{tot} : Total number of stress range blocks.

i : Stress range block index.

1.1.2

As the long term stress range distribution of a structural detail in a ship can be described by a two-parameter Weibull distribution, as given in Ch 9, Sec 1, [3.1.1], fatigue damage can be obtained by means of a closed- form equation, as given in [5].

1.2 Fatigue strength assessment

1.2.1

Assessment of the fatigue strength of structural members according to [2] includes the following three steps:

a) Calculation of stress ranges, according to [3].
b) Selection of the design S-N curve, according to [4].
c) Calculation of the cumulative damage and the fatigue life calculation, according to [5].

2 ACCEPTANCE CRITERIA

2.1 Fatigue life and acceptance criteria

2.1.1

The calculated fatigue life, T_F, is to comply with the following formula:

$T_F \geqslant T_{DF}$

3 REFERENCE STRESSES FOR FATIGUE ASSESSMENT

3.1 Fatigue stress range

3.1.1

The fatigue stress range for each load case of each loading condition is defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

The stress range of each loading condition *(j)* to be considered is the stress range obtained from the predominant load case, according to Ch 9, Sec 1, [7.1.2].

$$\Delta\sigma_{FS,(j)} = \max_i(\Delta\sigma_{FS,i(j)})$$

where:

$\Delta\sigma_{FS,i(j)}$: Fatigue stress range, in N/mm^2, for load case *(i)* of loading condition *(j)*, as defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

3.1.2 Welded joints

For welded joints, the fatigue stress range $\Delta\sigma_{FS,i(j)}$, in N/mm^2, corrected for mean stress effect, thickness effect and warping effect, is taken as:

- For simplified stress analysis:

$$\Delta\sigma_{FS,i(j)} = f_{mean,i(j)} \cdot f_{thick} \cdot f_{warp} \cdot \Delta\sigma_{HS,i(j)}$$

- For FE analysis:
  - For web-stiffened cruciform joints:

$$\Delta\sigma_{FS,i(j)} = f_w \cdot f_s \cdot \max(\Delta\sigma_{FS1,i(j)}, \Delta\sigma_{FS2,i(j)})$$

  - For other joints:

$$\Delta\sigma_{FS,i(j)} = \max_{(SideL,SideR)}[\max(\Delta\sigma_{FS1,i(j)}, \Delta\sigma_{FS2,i(j)})]$$

where:

f_w : correction factor for the effect of stress gradient along weld line given as 0.96

f_s : correction factor for the effect of supporting member given as 0.95

$\Delta\sigma_{HS,i(j)}$: Hot spot stress range, in N/mm^2, due to dynamic loads in load case (*i*) of loading condition *(j)* given in Ch 9, Sec 4, [2.1.1].

$\Delta\sigma_{FS1,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS1,i(j)}$

$$\Delta\sigma_{FS1,(j)} = f_{mean1,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS1,i(j)}$$

$\Delta\sigma_{FS2,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS2,i(j)}$

$$\Delta\sigma_{FS2,i(j)} = 0.9 \cdot f_{mean2,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS2,i(j)}$$

SideL, *SideR*: Left and right side respectively of the line A-A as shown in Ch 9, Sec 5, Figure 15 and Ch 9, Sec5, Figure 16.

$f_{mean1,\ i(j)}$: Correction factor for mean stress effect given in [3.2].

$f_{mean2,\ i(j)}$: Correction factor for mean stress effect given in [3.2].

f_{warp} : Correction factor due to warping effect, taken as:

- f_{warp} = 1.07 for the deck longitudinal stiffener of bulk carrier, the closest to the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1, except f_{warp} =1.0 when OST is not the dominant load case for all loading conditions
- f_{warp} = 1.04 for following deck longitudinal stiffeners of bulk carrier, except f_{warp} =1.0 when OST is not the dominant load case for all loading conditions
  - The closest stiffener to the longitudinal hatch coaming at one web frame away from the hatch corner, in way of the hatch opening as shown in Figure 1,
  - The second closest stiffener away from the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1,
- f_{warp} = 1.0 for the other cases.

$\Delta\sigma_{HS1,i(j)}$: Principal hot spot stress ranges, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition *(j)* which acts within ±45° of the perpendicular to the weld toe,

determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8- node).

$\Delta\sigma_{HS2,i(j)}$: Principal hot spot stress ranges, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition *(j)* which acts outside ±45°of the perpendicular to the weld toe, determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8- node).

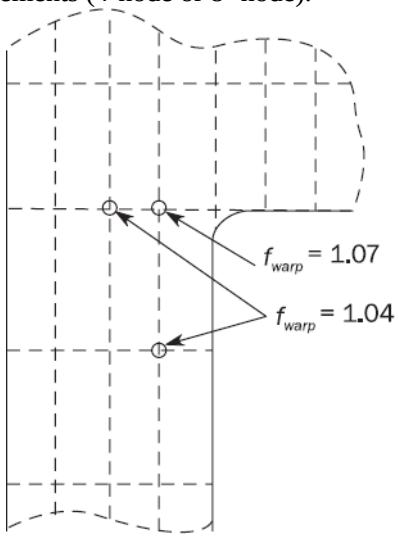


Figure 1 Warping effect on deck longitudinal stiffeners of bulk carrier

3.1.3 Base material free edge

For base material free edge, the fatigue stress range, $\Delta\sigma_{FS,i(j)}$ in N/mm^2, is taken as the local stress range at free edge, $\Delta\sigma_{BS,i(j)}$, as defined in Ch 9, Sec 1, [2.4] with correction factors:

$$\Delta\sigma_{FS,i(j)} = K_{sf} \cdot f_{material} \cdot f_{mean,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{BS,i(j)}$$

where:

K_{sf} : Surface finishing factor for base material given in [4.2.3].

$f_{material}$: Correction factor for material strength, taken as:

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

$\Delta\sigma_{BS,i(j)}$: Local stress range, in N/mm^2, due to dynamic loads in load case (*i*) of loading condition *(j)* taken as:

$$\Delta\sigma_{BS,i(j)} = \left|\sigma_{BS,i1(j)} - \sigma_{BS,i2(j)}\right|$$

$\sigma_{BS,i(j)}$, $\sigma_{BS,i(j)}$: Local stress, in N/mm^2, in load case '*i1*' and '*i2*' of loading condition *(j)*, obtained by very fine mesh FE analysis specified in Ch 9, Sec 5.

3.2 Mean stress effect

3.2.1 Correction factor for mean stress effect

The mean stress correction factor to be considered for each principal hot spot stress range of welded joint, $\Delta\sigma_{HS,i(j)}$, or for local stress range at free edge, $\Delta\sigma_{BS,\,i(j)}$, is taken as:

a) For welded joint:

$$f_{mean,i(j)} = \begin{cases} \min[1.0,\ 0.9 + 0.2\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{HS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} \geq 0 \\ \max[0.3,\ 0.9 + 0.8\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{HS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} < 0 \end{cases}$$

b) For base material:

$$f_{mean,i(j)} = \begin{cases} \min[1.0, 0.8 + 0.4\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{BS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} \geq 0 \\ \max[0.3, 0.8 + \dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{BS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} < 0 \end{cases}$$

where:

$$\sigma_{mCor,i(j)} = \begin{cases} \sigma_{mean,i(j)} & \text{for} \quad \sigma_{max} \leq R_{eEq} \\ R_{eEq} - \sigma_{max} + \sigma_{mean,i(j)} & \text{for} \quad \sigma_{max} > R_{eEq} \end{cases}$$

$$\sigma_{max} = \begin{cases} \max_{i,(j)}(\Delta\sigma_{HS,i(j)} + \sigma_{mean,i(j)}) & \text{for welded joint} \\ \max_{i,(j)}(\Delta\sigma_{BS,i(j)} + \sigma_{mean,i(j)}) & \text{for base material} \end{cases}$$

R_{eEq}= *max* (315 ; R_{eH})

$\sigma_{mean,\ i(j)}$: Fatigue mean stress, in N/mm^2, for base material calculated according to [3.2.2] or welded joint calculated according to [3.2.3] or [3.2.4] as applicable.

3.2.2 Mean stress for base material free edge

The fatigue mean stress for base material free edge, $\sigma_{mean,i(j)}$, in N/mm^2, due to static and dynamic loads case '*i1*' and '*i2*' of loading condition (*j)* is calculated by the following formula based on local stress:

$$\sigma_{mean,i(j)} = \frac{\sigma_{BS,i1(j)} + \sigma_{BS,i2(j)}}{2}$$

3.2.3 Mean stress for simplified method

The fatigue mean stress to be considered for welded joint assessed by the simplified stress analysis is to be obtained from Ch 9, Sec 4, [2.2].

3.2.4 Mean stress for FE analysis

The fatigue mean stresses for welded joint due to static and dynamic loads, $\sigma_{mean,i(j),pX}$, and$\sigma_{mean,i(j),pY}$, in N/mm^2, for load cases '*i1*' and '*i2*' of loading condition (j) ,belonging to the two principal hot spot stress range directions, *pX* and *pY*, is calculated by the following formula based on hot spot stress components as defined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3]:

$$\sigma_{mean,i(j)pX} = \frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} + (\sigma_{HS,i1(j)})_{yy} + (\sigma_{HS,i2(j)})_{yy}}{4} +$$
$$(\frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} - (\sigma_{HS,i1(j)})_{yy} - (\sigma_{HS,i2(j)})_{yy}}{4}) \cdot \cos 2\theta + (\frac{(\sigma_{HS,i1(j)})_{xy} + (\sigma_{HS,i2(j)})_{xy}}{4}) \cdot \sin 2\theta$$

$$\sigma_{mean,i(j)pY} = \frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} + (\sigma_{HS,i1(j)})_{yy} + (\sigma_{HS,i2(j)})_{yy}}{4} -$$
$$(\frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} - (\sigma_{HS,i1(j)})_{yy} - (\sigma_{HS,i2(j)})_{yy}}{4}) \cdot \cos 2\theta - (\frac{(\sigma_{HS,i1(j)})_{xy} + (\sigma_{HS,i2(j)})_{xy}}{4}) \cdot \sin 2\theta$$

θ :Angle between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system (Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [4.2.3]). The direction x of the element coordinate system is defined as the normal to the weld toe.

The one of the two mean stresses $\sigma_{mean,i(j),pX}$ and $\sigma_{mean,i(j),pY}$ which has a principal stress direction with an absolute value less than 45°is defined as $\sigma_{mean1,i(j)}$ belonging to $\Delta\sigma_{HS1,i(j)}$ The other mean stress is defined as$\sigma_{mean2,i(j)}$ belonging to $\Delta\sigma_{HS2\ ,i(j)}$.

3.3 Thickness effect

3.3.1

Plate thickness primarily influences the fatigue strength of welded joints through the effect of geometry, and through-thickness stress distribution. The correction factor, f_{thick},, for plate thickness effect is taken as:

- For $t_{n50} \leqslant 22$ mm, $f_{thick} = 1.0$.
- For $t_{n50} > 22$ mm, $f_{thick} = (t_{n50}/22)^n$

where:

t_{n50} : Net thickness of the considered member in way of the hot spot for welded joints or base material free edge, in mm.

- For simplified stress analysis, the net thickness to be considered for stiffeners is as follows:
  - Flat bar and Bulb profile: no correction,
  - Angle bar and T-bar: flange net thickness.
- For FE analysis, the net thickness to be considered is the net thickness of the member where the crack is likely to initiate and propagate.
  For 90°attachments, i.e. cruciform welded joints, transverse T-joints and plates with transverse attachment, the net thickness to be considered is to be taken as:

$$t_{n50} = \min\left(\frac{d}{2}, t_{1n50}\right)$$

n : Thickness exponent provided in Table 1 and Table 4 respectively for welded and non-welded joints. n is to be selected according to the considered stress direction. For this selection, $\Delta\sigma_{HS1}$ and $\Delta\sigma_{HS2}$ are considered perpendicular and parallel to the weld respectively.

d : Toe distance, in mm, as shown in Figure 2, taken as:
$d = t_{2n50} + 2\, l_{leg}$

t_{1n50} : Net thickness, in mm, of the continuous plate as shown in Figure 2.

t_{2n50} : Net thickness, in mm, of the transverse attach plate where the hot spot is assessed, as shown in Figure 2.

l_{leg} : Fillet weld leg length, in mm.

When post-weld treatment methods are applied to improve the fatigue life of considered welded joint, the thickness exponent is provided in [6].

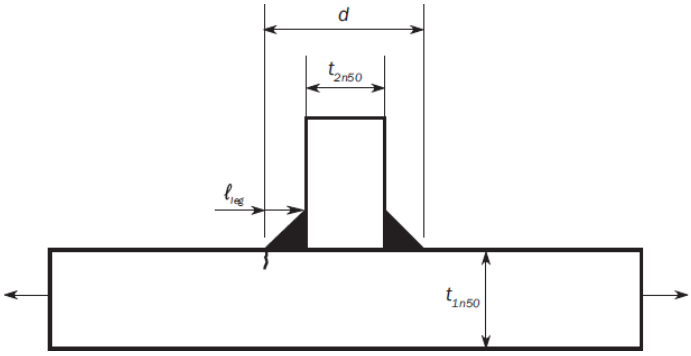


Figure 2 Toe distance for cruciform welded joints, transverse T-joints and plates with transverse attachment

4 S-N CURVES

4.1 Basic S-N curves

4.1.1 Capacity

The capacity of welded steel joints and steel base material with respect to fatigue strength is defined by S-N curves which provide the relationship between the stress range applied to the detail and the number of constant amplitude load cycles to failure.

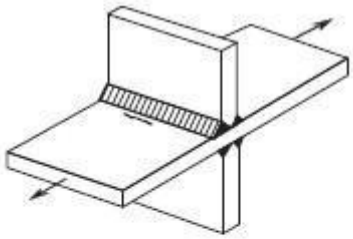
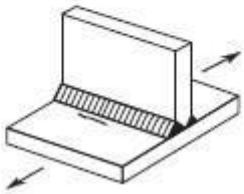
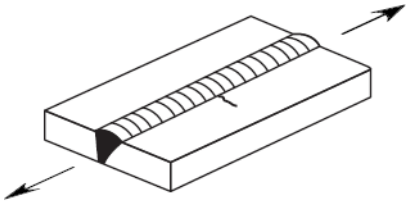
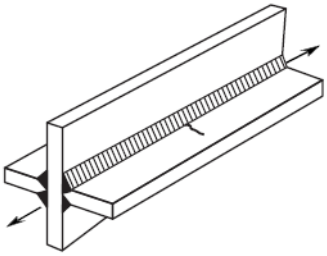
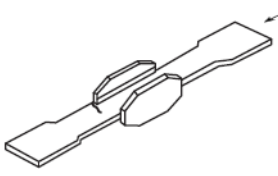
4.1.2 Design S-N curves

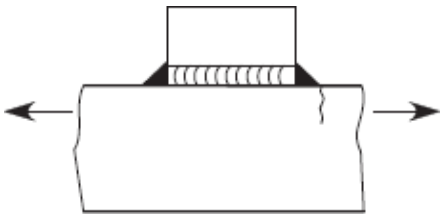
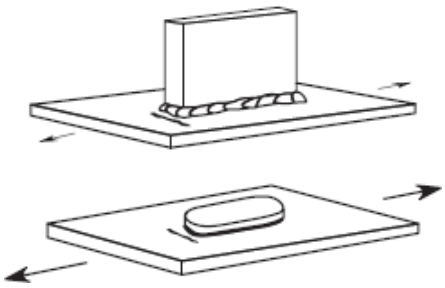
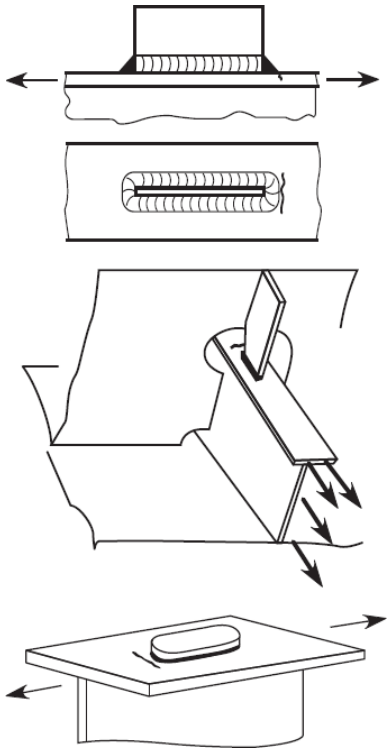
The fatigue assessment is based on use of S-N curves which are obtained from fatigue tests. The design S-N curves are established at two standard deviations below the mean S-N curves corresponding to 50% of probability of survival for relevant experimental data. Design S-N curves given in Table 2 and Table 3 correspond to a probability of survival of 97.7%.

4.1.3 S-N curve scope of application

The S-N curves are applicable to normal and high strength steels up to a specified minimum yield stress equal to 390 N/mm^2.

Welded joints: thickness exponents **Table 1**

No	Joint category description	Geometry	Condition	*n*
1	Cruciform joints, transverse T-joints, plates with transverse attachments		As-welded	0.25
			Weld toe treated by post-weld improvement method	0.2
2	Transverse butt welds		As-welded	0.2
			Ground flush or weld toe treated by post-weld improvement method	0.1
3	Longitudinal welds or attachments to plate edges		Any	0.1
		 	Weld toe treated by post-weld improvement method	0.1
(1) No benefit applicable for post-weld treatment of longitudinal end connections.				

No	Joint category description	Geometry	Condition	*n*
4	Longitudinal attachments on the flat bar or bulb profile		Any	0
			Weld toe treated by post-weld improvement method (1)	0
5	Longitudinal attachments and doubling plates		As-welded	0.2
			Weld toe treated by post-weld improvement method	0.1
6	Longitudinal attachments and doubling plates supported longitudinally		As-welded	0.1
			Weld toe treated by post-weld improvement method (1)	0
(1) No benefit applicable for post-weld treatment of longitudinal end connections.				

4.1.4 In-air environment

The basic design curves in-air environment shown in Figure 3 are represented by linear relationships between log ($\Delta\sigma$) and log (N) as follows:

$\log(N) = \log(K_2) - m \log(\Delta\sigma)$

where:

$\log(K_2) = \log(K_1) - 2\log(\delta)$

K_1 : Constant related to mean S-N curve, as given in Table 2.
K_2 : Constant related to design S-N curve, as given in Table 2.
δ : Standard deviation of log (N), as given in Table 2.
$\Delta\sigma_q$: Stress range at N = 107 cycles related to design S-N curve, in N/mm2, as given in Table 2.

Basic S-N curve data, in-air environment **Table 2**

Class	K_1		m	Standard deviation δ	K_2	Design stress range at 10^7 cycles	Design stress range at 2×10^6 cycles
	K_1	$\log_{10}K_1$		$\log_{10}\delta$	K_2	$\Delta\sigma_q$ N/mm^2	N/mm^2
B	2.343E15	15.3697	4.0	0.1821	1.01E15	100.2	149.9
C	1.082E14	14.0342	3.5	0.2041	4.23E13	78.2	123.9
D	3.988E12	12.6007	3.0	0.2095	1.52E12	53.4	91.3

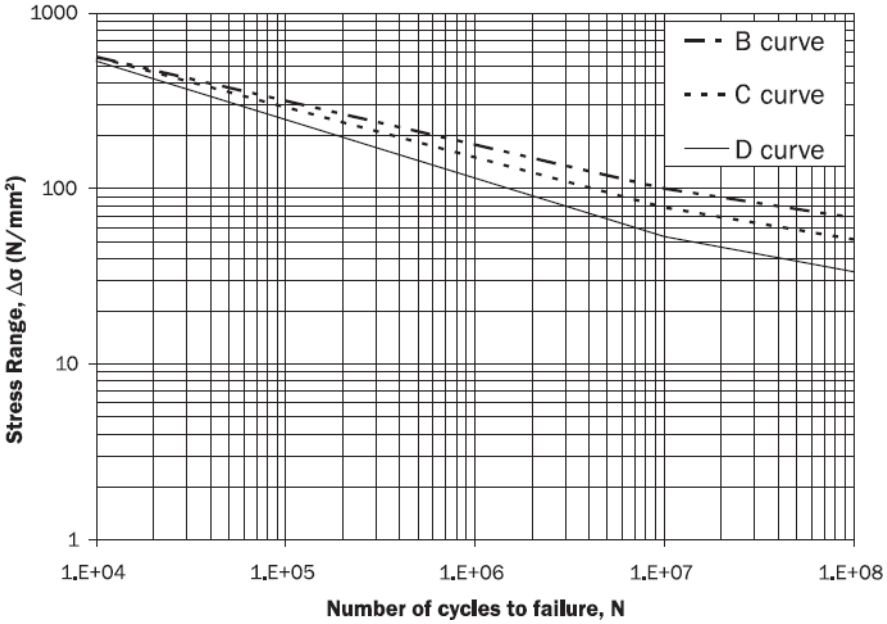


Figure 3 Basic design S-N curves, in-air environment

4.1.5 Corrosive environment

The basic design curves for corrosive environment shown in Figure 4 are represented by linear relationships between log ($\Delta\sigma$) and log (N) as follows:
$\log(N)=\log(K_2)-m\log(\Delta\sigma)$
N : Predicted number of cycles to failure under stress range .
K_2 : Constant related to design S-N curve as given in Table 3.

Basic S-N curve data, corrosive environment **Table 3**

Class	K_2	m	Design stress range at 2×10^6 cycles, N/mm^2
B_{corr}	5.05×10^{14}	4.0	126.1
C_{corr}	2.12×10^{13}	3.5	101.6
D_{corr}	7.60×10^{11}	3.0	72.4

4.2 Selection of S-N curves

4.2.1 Welded joints

For fatigue assessment of welded joints exposed to in-air environment, S-N curve D as defined in Table 2 is to be used. For corrosive environment, S-N curve D_{corr} as defined in Table 3 is to be used.

4.2.2 Base material free edge

For fatigue assessment of base material at free edge exposed to in-air environment, S-N curves B

or C as defined in Table 2 are to be used. For corrosive environment, S-N curves B_{corr} or C_{corr} as defined in Table 3 are to be used.

4.2.3 Surface finishing factor

The S-N curve *C* is applicable to most of non-welded locations taking into account the likelihood of some notching from corrosion, wear and tear in service with surface finishing factor as given in Table 4.

Higher surface finishing quality may be applied in using S-N curve *B* as given in Table 4, provided adequate protective measures are taken against wear, tear and corrosion and finite element analysis according Sec 5, [2] is carried out.

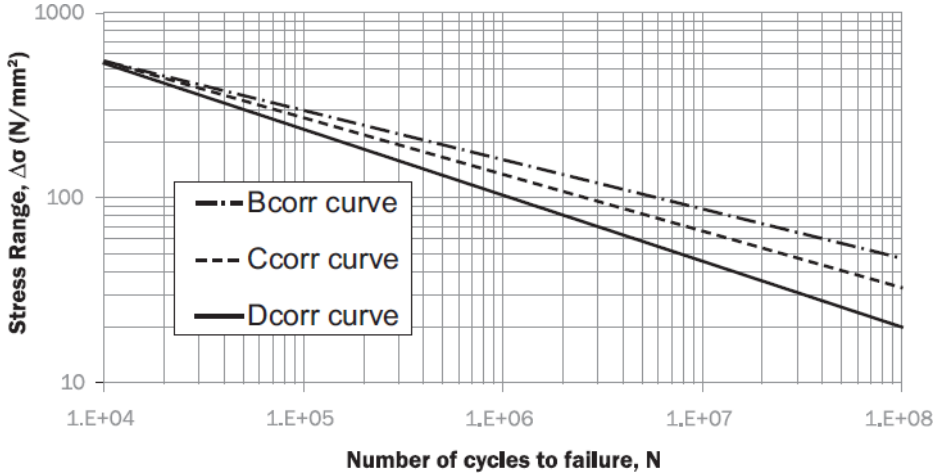
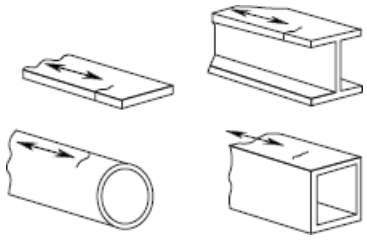
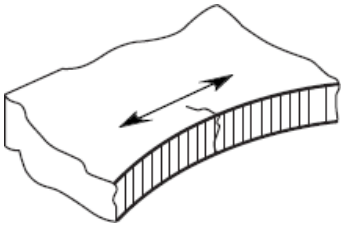


Figure 4 Basic design S-N curves, corrosive environment

ISC 4.2.3a Surface finishing factors are to be selected according to the joint configurations in Table 4, Section 3, Chapter 9 of this PART and submitted to ISC as the basis for selection of such factors corresponding to joint configurations. For the surface finishing factor corresponding to joint configuration 2, edge cutting process, edge treatment and surface finishing are to be taken into account.

Non-welded joints: thickness exponent and surface finishing factor **Table 4**

	Joint configuration, fatigue crack location and stress direction	Edge Cutting process	Edge treatment	Surface finishing	n	K_{sf}	S-N curve
1	Rolled or extruded plates and sections as well as seamless pipes, no surface or rolling defects 	N/A	N/A	No surface nor roll defect(1), (2)	0	0.94	B

Joint configuration, fatigue crack location and stress direction		Edge Cutting process	Edge treatment	Surface finishing	n	K_{sf}	S-N curve
2	Cut edges 	Machine-cutting e.g. by a thermal process. or sheared edge cutting.	Cutting edges chamfered or rounded by means of smooth grinding, groove direction parallel to the loading direction	Smooth surface free of cracks and notches[(1), (2)]	0.1	1.00	B
			Cutting edges broken or rounded.	Smooth surface free of cracks and notches. [(1), (2)]	0.1	1.07	B
			No edge treatment	Surface free of cracks and severe notches (inspection procedure) [(1), (2)]	0.1	1.0	C
		Manually thermally cut e.g. by flame cutting	No edge treatment	Surface free of cracks and severe notches (inspection procedure) [(1), (2)]	0.1	1.24	C
Note1: Stress increase due to geometry of cut-outs to be considered. Note2: Fine mesh FE analysis according to Sec 5, [2].							

5 FATIGUE DAMAGE CALCULATION

5.1 General

5.1.1

The design fatigue life is divided into a number of time periods due to different loading conditions and due to limitation of the corrosion protection.

It is assumed that the corrosion protection (i.e. coating system) is only effective for a limited number of years during which the structural details are protected, i.e. in-air environment. During the remaining part of the design life as specified in Table 5, the structural details are unprotected i.e. exposed to corrosive environment.

5.1.2

The elementary fatigue damage, given in [5.2], is the damage accumulated during a specific loading condition *(j)* associated with a specific environmental condition either protected condition, i.e. in-air environment, or unprotected condition, i.e. corrosive environment.

The combined fatigue damage, given in [5.3], is the combination of damage accumulated for a specific loading condition *(j)* for the in-air and corrosive environment time.

Total fatigue damage, given in [5.4], is the sum of the combined fatigue damages obtained for all loading conditions.

5.2 Elementary fatigue damage

5.2.1

The elementary fatigue damage for each fatigue loading condition *(j)* is to be calculated

independently for both protected in-air environment and unprotected corrosive environment, based on the fatigue stress range obtained for the predominant load case as follows:

$$D_{E(j)} = \frac{\alpha_{(j)} \cdot N_D}{K_2} \frac{\Delta\sigma_{FS,(j)}^m}{\left(\ln N_R\right)^{m/\xi}} \cdot \mu_{(j)} \cdot \Gamma\left(1+\frac{m}{\xi}\right)$$

where:

N_D : Total number of wave cycles experienced by ship during the design fatigue life, taken as:
$N_D = 31.557 \times 106\ (f_0 T_D) / (4 \log L)$

f_0 :Factor taking into account time in seagoing operations excluding time in loading and unloading, repairs, etc.
$f_0 = 0.85$.

$\alpha_{(j)}$: Fraction of time in each loading condition given in Ch 9, Sec 1, Table 1 for oil tanker and in Ch 9, Sec1, Table 3 for bulk carrier.

$\Delta\sigma_{FS,i(j)}$: Fatigue stress range at the reference probability level of exceedance of 10^{-2}, in N/mm^2.

N_R : Number of cycles corresponding to the reference probability of exceedance of 10^{-2}.
$N_R = 100$.

ξ : Weibull shape parameter,
$\xi = 1$.

$\Gamma(x)$: Complete Gamma function.

K_2 : Constant of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

$\mu_{(j)}$: Coefficient taking into account the change of inverse slope of the S-N curve, m,

- For in-air environment:

$$\mu_{(j)} = 1 - \frac{\left\{\gamma\left(1+\frac{m}{\xi}, \nu_{(j)}\right) - \nu_{(j)}^{-\Delta m/\xi} \cdot \gamma\left(1+\left(\frac{m+\Delta m}{\xi}\right), \nu_{(j)}\right)\right.}{\Gamma\left(1+\frac{m}{\xi}\right)}$$

$$\nu_{(j)} = \left(\frac{\Delta\sigma_q}{\Delta\sigma_{FS,(j)}}\right)^{\xi} \ln N_R$$

- For corrosive environment:
$\mu_{(j)} = 1.0$

$\gamma(a,x)$: Incomplete Gamma function.

$\Delta\sigma_q$: Stress range, in N/mm^2, corresponding to the intersection of the two segments of design S-N curve at $N=10^7$ cycles, as given in Table 2.

Δm : Change in inverse slope of S-N curve at $N=10^7$ cycles.
$\Delta m = 2$

5.3 Combined fatigue damage

5.3.1

The combined fatigue damage in protected in-air environment and unprotected corrosive environment for each loading condition *(j)* is to be calculated as follows:

$$D_{(j)} = D_{E,air(j)} \cdot \frac{T_D - T_C}{T_D} + D_{E,corr(j)} \cdot \frac{T_C}{T_D}$$

where:

$D_{E,air(j)}$: The elementary fatigue damage for in-air environment for loading condition *(j)* given in [5.2.1].

$D_{E,corr(j)}$: The elementary fatigue damage for corrosive environment for loading condition *(j)* as calculated in [5.2.1].

5.4 Total fatigue damage

5.4.1

The total fatigue damage for all applicable loading conditions is calculated as follows:

$$D = \sum_{j=1}^{n_{LC}} D_{(j)}$$

where:

$D_{(j)}$: Combined fatigue damage for each applicable loading condition, as given in [5.3].

Time in corrosive environment, T_C **Table 5**

Location of weld joint or structural detail	Time in corrosive environment T_C, in years
Water ballast tank	10
Oil cargo tank	
Lower part (1) of bulk cargo hold and water ballast cargo hold	
Bulk cargo hold and water ballast cargo hold except lower part (1)	5
Void space Other areas	
(1) Lower part means cargo hold part below a horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or 300 mm below the hopper tank upper end for holds of double side skin construction (see Pt 2, Ch 1, Sec 2, Figure 1).	

5.5 Fatigue life calculation

5.5.1

The fatigue life, T_F, is taken as:

$$T_F = \frac{T_D}{D_{air}} \qquad \text{if} \quad \frac{T_D}{D_{air}} \le (T_D - T_C)$$

$$T_F = T_D - T_C + \left(\frac{T_D}{D_{air}} - T_D + T_C \right) \frac{D_{air}}{D_{corr}} \qquad \text{otherwise.}$$

where:

D_{air} : Total fatigue damage for all loading conditions in-air environment taken as:

$$D_{air} = \sum_{j=1}^{n_{LC}} D_{E,air(j)}$$

D_{corr} : Total fatigue damage for all loading conditions in corrosive environment taken as:

$$D_{corr} = \sum_{j=1}^{n_{LC}} D_{E,corr(j)}$$

6 WELD IMPROVEMENT METHODS

6.1 General

6.1.1

Post-weld fatigue strength improvement methods are to be considered as a supplementary means of achieving the required fatigue life, and subjected to quality control procedures and corrosion protection in accordance with Pt 1, Ch 3, Sec 4.

6.1.2 Limitation of the benefit of post-weld treatment

For structural details where the benefit of post-weld treatment is applicable, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than T_{DF} / 1.47.

However, for structural details inside a bulk cargo hold the calculated fatigue life at design stage excluding post-weld treatment effects is not to be less than 25 years.

Note1: When T_{DF} is taken equal to 25 years, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than 17 years.

6.1.3 Post-weld treatment at fabrication stage

There is one basic post-weld treatment method considered in these Rules to improve fatigue strength at the fabrication stage, i.e. weld geometry control and defect removal method by burr grinding.

6.1.4 Weld toe

The improvement method is applied to the weld toe. Thus, it is intended to increase the fatigue life of the weld from the viewpoint of a potential fatigue failure arising at the weld toe. The possibility of failure initiation at other locations is always to be considered. If the failure is shifted from the weld toe to the root by applying post- weld treatment, there may be no significant improvement in the overall fatigue performance of the joint. Improvements of the weld root cannot be expected from treatment applied to weld toe.

A brief description of the method and the degree of improvement which can be achieved is given in [6.2].

6.1.5 Weld type for post-weld treatment

When weld improvements are planned, full or partial penetration welds with a minimum root face according to Ch 12, Sec 3, [2.4] are to be used to mitigate or to eliminate the possibility of cracking at the weld root.

6.2 Weld toe burr grinding

6.2.1

The weld may be machined using a burr grinding tool to produce a favourable shape to reduce stress concentrations and remove defects at the weld toe, see Figure 5. In order to eliminate defects, such as intrusions, undercuts and cold laps, the material in way of the weld toe is to be removed. The depth of grinding shall be at least 0.5mm below the bottom of any visible undercut. The total depth of the burr grinding is not to be greater than the lesser of 2 mm and of 7% the local gross thickness of the machined plate. Any undercut not complying with this requirement is to be repaired by an approved method.

6.2.2

To avoid introducing a detrimental notch effect due to small radius grooves, the burr diameter is to be scaled to the plate thickness at the weld toe being ground. The diameter is to be in the 10 to 25 mm range for application to welded joints with plate thickness from 10 to 50 mm. The resulting root radius of the groove is to be no less than 0.25 t_{as_built}. The weld throat thickness and leg length after burr grinding must comply with the rule requirements or any increased weld sizes as indicated on the approved drawings.

The inspection procedure is to include a check of the weld toe radius, the depth of burr grinding, and confirmation that the weld toe undercut has been removed completely.

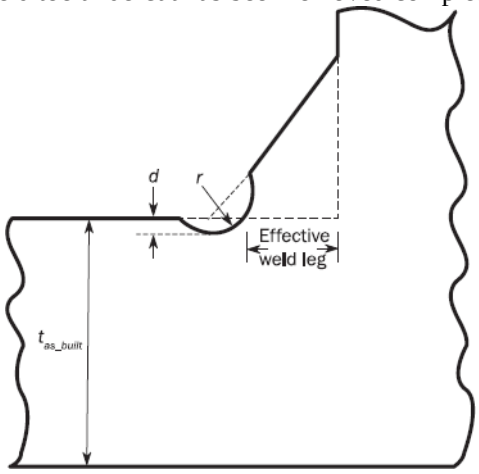


Figure 5 Details of ground weld toe geometry

6.3 Fatigue improvement factor

6.3.1

The benefit of burr grinding corresponds to an increase in fatigue strength by a factor of 1.3 (i.e. a

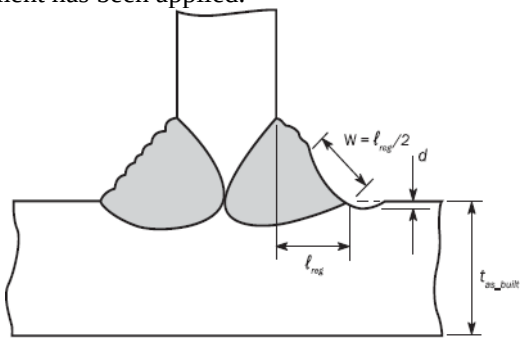
reduction of the effective stress range by 1.3), reducing the damage in air to D_{air} / 2.2,
where:
D_{air} : Fatigue damage in air as given in Ch 9, Sec 3, [5.3.1].

6.4 Applicability

6.4.1

The application of post-weld improvement and fatigue improvement factor provided in this section is subject to following limitations:

- The weld type complies with [6.1.5].
- The weld improvement is effective in improving the fatigue strength of structural details under high cycle fatigue conditions therefore the fatigue improvements factors do not apply to low-cycle fatigue conditions, i.e. when N⩽5×104, where N is the number of life cycles to failure.
- Unless otherwise specifically stated, the fatigue improvement factor is to be used for welds, joining steel plates which are between 6 and 50 mm thick.
- Fatigue improvement factor is to be applied to as-welded transverse butt welds, as-welded T-joint and cruciform welds and as-welded longitudinal attachment welds excluding longitudinal end connections.
- In way of areas prone to mechanical damage, fatigue improvement may only be granted if these are adequately protected.
- Treatment of inter-bead toes is required for large multi-pass welds as shown in Figure 6.
- The builder is to provide the list of details and their locations on the ship for which the post-weld treatment has been applied.



l_{leg}: Weld leg length.
W : Width of groove.
d : Depth of grinding.

Figure 6 Extent of weld toe burr grinding to remove inter-bead toes on weld face

7 WORKMANSHIP

7.1 Application

7.1.1

In general, the fatigue performance of structural details can be improved by adopting enhanced workmanship standards, which include building alignment and weld control.

7.2 Workmanship control for construction details

7.2.1 Building alignment and tolerance control

Building alignment exceeding construction tolerance could introduce additional stress concentration for structural details, reducing the fatigue performance. The builder is responsible to comply with the construction requirements given in Ch 12, Sec 1.

7.2.2 Weld profile control

Poor weld geometry could introduce additional stress concentration; therefore special attention should be given to achieving a favourable geometry and smooth transition at the weld toe. Weld profile control, i.e. enhanced workmanship may be required by the Society in way of critical weld toe locations.
The weld notch stress concentration is a direct function of the weld flank angle and the weld toe radius.

The validity of the aforementioned S-N curves is based on a weld flank angle with a maximum mean value of 50 deg and on a weld toe radius with a minimum mean value of 0.5 mm. Welding details may be requested to be submitted for approval for some critical areas considering the calculated fatigue life.

ISC 7.2.2a For weld toe in critical locations, reference may be made to the requirements of 3.3.1 of ISC Guidelines for Construction Monitoring of Hull Structures.

7.2.3 Post-weld treatment methods

Post-weld treatment methods may be used to improve fatigue resistance of structural detail, as specified in [6].

At the design stage, the calculated fatigue life should not generally take into account any benefit that may be derived from such treatment. This benefit should only be considered in exceptional cases when the design fatigue life can not reasonably be achieved by adopting alternative design measures such as improvement of the shape of the cut-outs, soft brackets toes, local increase in thickness or other changes in geometry of the structural detail. This is to be considered on a case-by-case basis by the Society.

ISC 7.2.3a Where the benefit derived from the post-weld treatment is taken into account, the relevant workmanship requirements of post-weld treatment need to be approved by ISC.

ISC 7.2.3b Where grinding is applied, the following requirements are to be complied with: The grinding standard of structural details including the extent, smoothness particulars, final weld profile, grinding workmanship and quality acceptance criteria are to be clearly shown on the applicable drawings and submitted for review together with supporting calculations. The applicable conditions, methods and workmanship requirements for grinding are to be in accordance with paragraph 6, Section 3, Chapter 9 of this PART. Grinding has to extend to areas well outside the high stress region.

7.2.4 Detail design standard

Requirements for improved design of structural details are provided in Ch 9, Sec 6. The detail design standard also includes workmanship and welding requirements.

Section 4 SIMPLIFIED STRESS ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes dynamic load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3.1].
'i1' denotes dynamic load case HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S
'i2' denotes dynamic load case HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:
'Full load' or 'Normal ballast' for oil tankers, as defined in Ch 9, Sec 1, [6.2].
'Full load homogeneous', 'Full load alternate', 'Normal ballast' or 'Heavy ballast' for bulk carriers, as defined in Ch 9, Sec 1, [6.3].

l_{bdg} : Effective bending span of stiffener, in m, as defined in Ch 3, Sec 7.

$I_{y\text{-}n50}$: Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4.

$I_{z\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4.

y : Transverse coordinate of the load calculation point under consideration, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

f_c : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{NA} : Correction factor taken as:

- For bulk carrier:
  - $f_{NA} = 1.0$ for $0 < z \leqslant D/2$
  - $f_{NA} = 0.95$ for $z = D$
  - f_{NA} : linear interpolation for other values of z
- For oil tanker: $f_{NA} = 1.0$

K_a : Geometrical stress concentration factor for stress due to axial load given in [5.2].

K_b : Geometrical stress concentration factor for stress due to lateral pressure given in [5.2].

K_n : Stress concentration factor due to unsymmetrical stiffener geometry, as defined in [5.1].

1 GENERAL

1.1 Application

1.1.1

This section defines the procedure for a simplified stress assessment which is to be used to evaluate the fatigue strength of the longitudinal stiffener end connections.

1.1.2

The hot spot stress ranges and hot spot mean stresses in way of each end connection of longitudinal stiffener, as shown in Figure 2 are to be evaluated at the flange of the longitudinal stiffener in the following locations:

a) Transverse webs or floors other than those located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement is not to be considered.

b) Transverse webs or floors located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement are to be considered.

Stress concentration factors due to unsymmetrical stiffener geometry according [5.1] and due to the stiffener end connection geometry at point 'A' and 'B' according to [5.2] are to be applied.

1.2 Assumptions

1.2.1

The following assumptions are made in the fatigue assessment for longitudinal stiffener end connections:

1.2.1 The hot spot stress is based on:

a) Nominal stresses.

b) Stress concentration factors given in [5].

c) Loading conditions specified in Ch 9, Sec 1, [6].

1.2.2 The longitudinal stiffener end connection types are described in [5.2].

1.2.2

The end connections given in [5.2] are based on typical joint geometry under axial and lateral loadings. When a structural detail is different from those shown in Table 4, a finite element analysis is to be used to demonstrate the adequacy of the detail in terms of fatigue strength, according to [5.3].

2 HOT SPOT STRESS

2.1 Hot spot stress range

2.1.1

The hot spot stress range, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition (*j*) is obtained from the following formula:

$$\Delta\sigma_{HS,i(j)} = \left|\left(\sigma_{GD,i1(j)} + \sigma_{LD,i1(j)} + \sigma_{dD,i1(j)}\right) - \left(\sigma_{GD,i2(j)} + \sigma_{LD,i2(j)} + \sigma_{dD,i2(j)}\right)\right|$$

where:

$\sigma_{GD,i1(j)}$,$\sigma_{GD,i2(j)}$: Stresses due to global hull girder wave bending moments, in N/mm^2, as defined in [3.1.1].

$\sigma_{LD,i1(j)}$,$\sigma_{LD,i2(j)}$: Stresses due to local dynamic pressure, in N/mm^2, as defined in [4.1.1].

$\sigma_{dD,i1(j)}$,$\sigma_{dD,i2(j)}$: Stresses due to relative displacement in wave, in N/mm^2, as defined in [4.2.4] and [4.2.5].

2.2 Hot spot mean stress

2.2.1

The hot spot mean stress, in N/mm^2, due to static and dynamic loads for load case (*i*) of loading condition (*j*) is obtained from the following formula:

$$\Delta\sigma_{mean,i(j)} = \sigma_{GS,(j)} + \sigma_{LS,(j)} + \sigma_{dS,(j)} + \sigma_{mLD,i(j)} + \sigma_{mGD,i(j)}$$

where for the load case (*i*) of loading condition (*j*):

$\sigma_{GS,(j)}$: Stress due to still water hull girder bending moment, in N/mm^2, as defined in [3.2.1].

$\sigma_{LS,(j)}$: Stress due to local static pressure, in N/mm^2, as defined in [4.1.2].

$\sigma_{dS,(j)}$: Stress due to relative displacement in still water, in N/mm^2, as defined in [4.2.7].

$\sigma_{mLD,i(j)}$: Mean stress due to local dynamic pressure, in N/mm^2, as defined as:

$$\sigma_{mLD,i(j)} = \frac{\sigma_{LD,i1(j)} + \sigma_{LD,i2(j)}}{2}$$

$\sigma_{LD,i1(j)}$, $\sigma_{LD,i2(j)}$: Stress due to local dynamic pressure, in N/mm^2, as defined in [4.1.1].

$\sigma_{mGD,i(j)}$: Mean stress due to global wave bending moment, in N/mm^2, as defined as:

$$\sigma_{mGD,i(j)} = \frac{\sigma_{GD,i1(j)} + \sigma_{GD,i2(j)}}{2}$$

$\sigma_{GD,i1(j)}$, $\sigma_{GD,i2(j)}$: Stress due to global wave bending moment, in N/mm^2, as defined in [3.1.1].

3 HULL GIRDER STRESS

3.1 Stress due to hull girder wave bending moments

3.1.1

The hull girder hot spot stress, in N/mm^2, for load cases *i1* and *i2* of loading condition (*j*) is obtained from the following formula:

$$\sigma_{GD,ik(j)} = f_c \cdot K_a \left(\frac{M_{wv-LC,ik}}{I_{y-n50}}(z - z_n) \cdot f_{NA} - \frac{M_{wh-LC,ik}}{I_{z-n50}} y\right) 10^{-3}$$

where:

$M_{wv\text{-}LC,\ ik}$: Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (*j*) for *ik* being equal to *i*1 and *i*2.

$M_{wh\text{-}LC,\ ik}$: Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (*j*) for *ik* being equal to *i*1 and *i*2.

3.2 Stress due to still water hull girder bending moment

3.2.1

The hull girder hot spot stress due to still water bending moment, in N/mm^2, in loading condition (*j*) is obtained from the following formula:

$$\sigma_{GS,(j)} = \frac{f_c \cdot f_{NA} \cdot K_a \cdot \beta_{(j)} \cdot M_{sw} \cdot (z - z_n)}{I_{y-n50}} 10^{-3}$$

where:

M_{sw} : Permissible still water vertical bending moment, in kNm, as defined in Ch 4, Sec 4 at the hull girder load calculation point of the considered longitudinal position.

$\beta_{(j)}$: Fraction of permissible still water vertical bending moment, as defined in Table 1.

Fraction of permissible still water vertical bending moments, $\beta_{(j)}$ **Table 1**

Ship type	Loading conditions	Longitudinal position on the considered section	$\beta_{(j)}$
Oil tankers	Homogeneous	N/A	0.60 in sagging condition
	Normal ballast		0.80 in hogging condition
Bulk carriers	Homogeneous		0.40 in sagging condition
	Alternate		0.75 in hogging condition
	Normal ballast		0.80 in hogging condition
	Heavy ballast (See Figure 1)	Ballast hold	0.75 in sagging condition
		Cargo holds adjacent to ballast hold	Linear interpolation between 0.75 in sagging condition and 0.45 in hogging condition
		Other cargo holds	0.45 in hogging condition

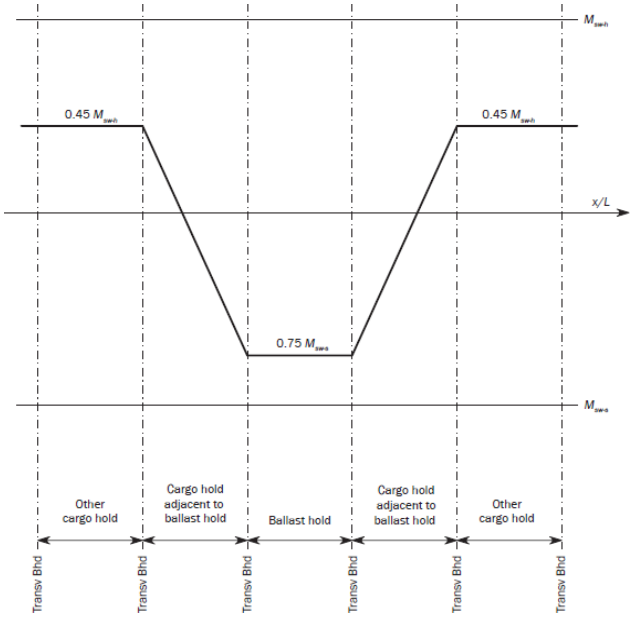


Figure 1 Distribution of still water bending moment for fatigue assessment in way of ballast hold

4 LOCAL STIFFENER STRESS

4.1 Stress due to stiffener bending

4.1.1 Stress due to dynamic pressure

The hot spot stress, in N/mm^2, due to local dynamic pressure in load case *i*1 and *i*2 for loading condition (*j*) is obtained from the following formula:

$$\sigma_{LD,ik(j)} = \frac{K_b K_n s l_{bdg}^2 (\eta_W f_{NL} P_{W,ik(j)} + \eta_{ld} P_{Id,ik(j)} + \eta_{bd} P_{bd,ik(j)}) \left(1 - \frac{6x_e}{l_{bdg}} + \frac{6x_e^2}{l_{bdg}^2}\right)}{12 Z_{eff-n50}}$$

where:

$P_{W,\,ik(j)}$: Dynamic wave pressure, at the mid span, in kN/m^2, specified in Ch 4, Sec 5, [1.4], in load case *i*1 and *i*2 for loading condition (*j*).

$P_{ld,\,ik(j)}$: Dynamic liquid tank pressure, at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [1.1.1], in load case *i*1 and *i*2 for loading condition (*j*).

Pressure acting on both sides of the stiffener, i.e. applied on the attached plate on stiffener side or on opposite side to the stiffener, could be simultaneously considered if relevant in the loading condition.

For the deck longitudinal stiffeners of bulk carriers, no internal pressure from the topside tank is considered.

$P_{bd,\,ik(j)}$: Dynamic dry bulk cargo pressure at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [2.4.1], in load case *i*1 and *i*2 for loading condition (*j*).

η_w, η_{ld}, η_{bd}: Pressure normal coefficients, taken as:

$\eta = 1$ when the considered pressure is applied on the stiffener side,

$\eta = -1$ otherwise.

f_{NL} : Correction factor for the non-linearity of the wave pressure taken as:

$$f_{NL} = 1 \qquad z > T_{LC} + 2h_w$$

$$f_{NL} = 2.5\frac{z - T_{LC}}{h_w} - 4 \qquad T_{LC} + 1.8h_w < z \le T_{LC} + 2h_w$$

$$f_{NL} = 0.5\frac{z - T_{LC}}{h_w} - 0.4 \qquad T_{LC} + 1.6h_w < z \le T_{LC} + 1.8h_w$$

$$f_{NL} = 0.4 \qquad T_{LC} + 1.2h_w < z \le T_{LC} + 1.6h_w$$

$$f_{NL} = 0.7 - 0.25\frac{z - T_{LC}}{h_w} \qquad T_{LC} + 0.6h_w < z \le T_{LC} + 1.2h_w$$

$$f_{NL} = 1 - 0.75\frac{z - T_{LC}}{h_w} \qquad T_{LC} - 0.2h_w < z \le T_{LC} + 0.6h_w$$

$$f_{NL} = 0.1875\frac{z - T_{LC}}{h_w} + 1.1875 \qquad T_{LC} - h_w < z \le T_{LC} - 0.2h_w$$

$$f_{NL} = 1 \qquad z \le T_{LC} - h_w$$

h_w : Water head equivalent to the pressure at waterline, in m, as defined in Ch 4, Sec 5.

x_e : Distance, in m, to the hot spot from the closest end of the span l_{bdg}, as defined in Figure 2.

$Z_{eff\text{-}n50}$: Net section modulus, in cm^3, of the considered stiffener calculated considering an effective breadth b_{eff} of attached plating.

b_{eff} : Effective breadth, in mm, of attached plating specified at the ends of the span and in way of end brackets and supports, taken as:

$$b_{eff} = s \cdot \min\left[\frac{1.04}{1 + \frac{3}{\left(\frac{l_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right) \cdot 10^3\right)^{1.35}}}; 1.0\right] \qquad \text{for} \quad \frac{l_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right) \times 10^3 \ge 1$$

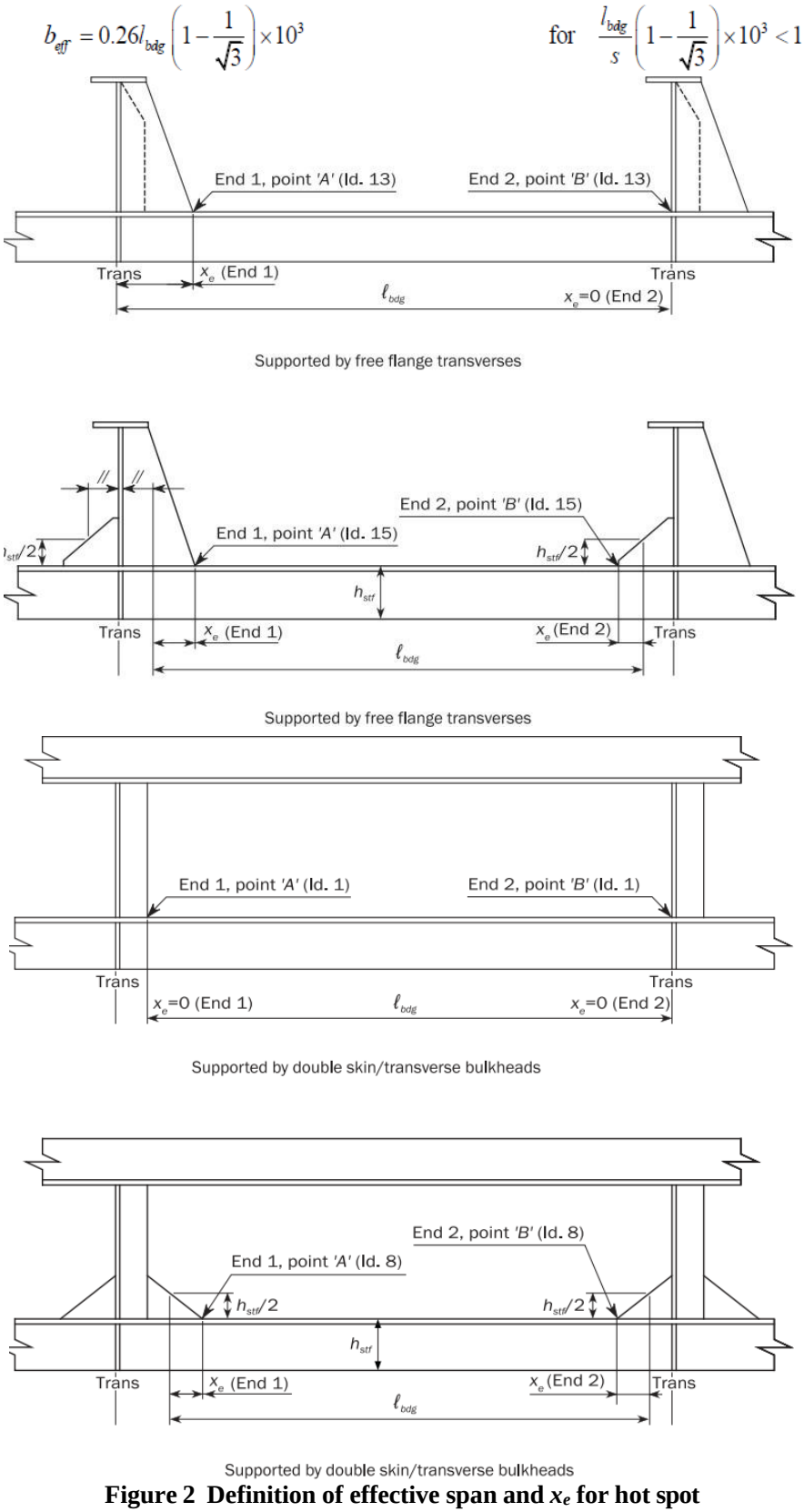


Figure 2 Definition of effective span and x_e for hot spot

4.1.2 Stress due to static pressure

The hot spot stress due to local static pressure, in N/mm2, for loading condition (*j*) is obtained from the following formula:

$$\sigma_{LS,(j)} = \frac{K_b K_n s l_{bdg}^2 (\eta_s P_{s,(j)} + \eta_{ls} P_{ls,(j)} + \eta_{bs} P_{bs,(j)}) \left(1 - \frac{6x_e}{l_{bdg}} + \frac{6x_e^2}{l_{bdg}^2}\right)}{12 Z_{eff-n50}}$$

where:

$P_{S,(j)}$: Static external pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 5, [1.2].

$P_{ls,(j)}$:Static liquid tank pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [1.1.1].Pressure acting on both sides could be simultaneously considered if relevant in the loading condition.

$P_{bs,(j)}$: Static dry bulk cargo pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [2.4.1].

η_s, η_{ls}, η_{bs} : Pressure normal coefficients, taken as:

η = 1 when the considered pressure is applied on the stiffener side,

η = -1 otherwise.

4.2 Stress due to relative displacement

4.2.1 General

For longitudinal stiffener end connections fitted on transverse web or floor located

- At transverse bulkhead including swash bulkhead of cargo hold or
- In way of stool,

the additional hot spot stress due to the relative displacement is to be considered.

4.2.2 Relative displacement definition

The relative displacement is defined as follows.

- For longitudinals penetrating floors in way of stool the relative displacement is defined as the displacement of the longitudinal measured at the first floor forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the floor in way of stool.
- For other longitudinals, the relative displacement is defined as the displacement of the longitudinal measured at the first transverse web frame (or floor) forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the transverse bulkhead including swash bulkhead.

4.2.3 Sign convention

Where the stress at the hot spot location, i.e. at the flange of longitudinal, due to relative displacement is in tension, the sign of the relative displacement is positive.

4.2.4 Oil tankers

The additional hot spot stress due to relative displacement for load case $i1$ and $i2$ of loading condition (j) for an oil tanker is to be accounted for either using finite element method as described in [4.2.6] or by applying a stress factor on the local dynamic stress component as described in the following:

$$\sigma_{dD,ik(j)} = (K_d - 1) \cdot \sigma_{LD,ik(j)}$$

where:

$\sigma_{LD,ik(j)}$: Local dynamic stress defined in [4.1.1].

K_d : Bending stress factor for longitudinal stiffeners caused by relative displacement between supports, shown on Figure 3, as given in Table 2.

Bending stress factor of longitudinals due to relative displacement between transverse bulkhead (including swash bulkhead) and adjacent web frames (floors) Table 2

Location		K_d factor	
		Full load condition	Ballast condition
Bottom longitudinal	Mid position between longitudinal bulkhead, bottom girders or buttress structure	1.50	
	At longitudinal bulkhead, bottom girders (except centre line girder) or buttress structure	1.15	
	At centre line girder	1.30	
	Intermediate position between above bottom positions	Linear interpolation	
Side longitudinals	Mid position between lowest side stringer and deck at side	1.30	1.15
	Lowest side stringer and deck at side	1.15	1.15
	Intermediate positions	Linear interpolation	1.15
Other longitudinals		1.15	

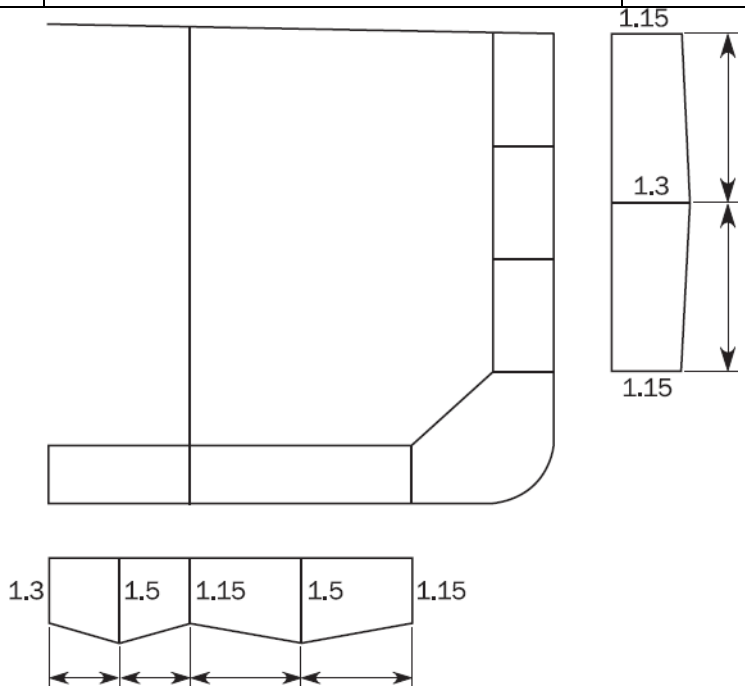


Figure 3 K_d factor in full load condition for oil tanker with two longitudinal bulkheads

4.2.5 Bulk carriers

The additional hot spot stress due to relative displacement for load case *i1* and *i2* of loading condition (*j*) for a bulk carrier is to be calculated using finite element method as described in [4.2.6].

4.2.6 Stress due to relative displacement derived using FE method

The following procedure is based on a cargo hold model complying with Ch 7, Sec 2, [2] to calculate the stress due to relative displacements. The stress due to relative displacements, in N/mm2, for load case *i1* and *i2* of loading condition (*j*) for both locations "*a*" and "*f*" is to be calculated directly using the following expression:

$$\sigma_{dD,ik(j)} = \begin{cases} K_b\sigma_{dFwd-a,ik(j)} + K_b\sigma_{dAft-a,ik(j)} & \text{for location "}a\text{"} \\ K_b\sigma_{dFwd-f,ik(j)} + K_b\sigma_{dAft-f,ik(j)} & \text{for location "}f\text{"} \end{cases} \quad (k = 1, 2)$$

where:

a, f : Suffix which denotes the location as indicated in Figure 4.

Aft, Fwd : Suffix which denotes the direction, afterward (*Aft*) or forward (*Fwd*), from the transverse bulkhead. as shown in Figure 4.

K_b : Stress concentration factor due to bending for the location '*a*' or '*f*' which may correspond to points '*A*' or '*B*' as defined in Table 4.

$\sigma_{dFwd\text{-}a,ik(j)}, \sigma_{dAft\text{-}a,ik(j)}, \sigma_{dFwd\text{-}f,ik(j)}, \sigma_{dAftd\text{-}f,ik(j)}$: Additional stress at location '*a*' and '*f*', in N/mm^2, due to the relative displacement between the transverse bulkhead including swash bulkhead or floors in way of stool and the forward (*Fwd*) and afterward (*Aft*) transverse web or floor respectively for load case *i1* and *i2* of loading condition (*j*), taken as:

$$\sigma_{dFwd-a,ik(j)} = \frac{3.9\delta_{Fwd,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Aft-n50} l_{Fwd} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eAft}|}{l_{Aft}}\right) 10^{-5}$$

$$\sigma_{dAft-a,ik(j)} = \left[\frac{3.9\delta_{Aft,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Aft-n50} l_{Aft} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eAft}|}{l_{Aft}}\right) - \frac{0.9\delta_{Aft,ik(j)} EI_{Aft-n50} |x_{eAft}|}{Z_{Aft-n50} l_{Aft}^3}\right] 10^{-5}$$

$$\sigma_{dFwd-f,ik(j)} = \left[\frac{3.9\delta_{Fwd,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Fwd-n50} l_{Fwd} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eFwd}|}{l_{Fwd}}\right) - \frac{0.9\delta_{Fwdt,ik(j)} EI_{Fwd-n50} |x_{eFwd}|}{Z_{Fwd-n50} l_{Fwd}^3}\right] 10^{-5}$$

$$\sigma_{dAft-f,ik(j)} = \frac{3.9\delta_{Aft,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Fwdt-n50} l_{Aft} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eFwd}|}{l_{Fwd}}\right) 10^{-5}$$

$I_{Fwd\text{-}n50}, I_{Aft\text{-}n50}$: Net moment of inertia, in cm^4, of forward (*Fwd*) and afterward (*Aft*) longitudinal.

$Z_{Fwd\text{-}n50}, Z_{Aft\text{-}n50}$: Net section modulus of forward (*Fwd*) and afterward (*Aft*) stiffener, in cm^3.

l_{Fwd}, l_{Aft} : Span, in m, of forward (*Fwd*) and afterward (*Aft*) longitudinal, as shown in Figure 4.

x_{eFwd}, x_{eAft} : Distance, in m, as shown in Figure 2, to the hot spot in location '*a*' or '*f*' from the closest end of l_{Fwd} and l_{Aft} respectively.

$\delta_{Fwd,ik(j)}, \delta_{Aft,ik(j)}$: Relative displacement in the direction perpendicular to the attached plate, in mm, between the transverse bulkhead (including swash bulkhead or floor in way of stools) and the forward (*Fwd*) or afterward (*Aft*) transverse web (or floor) as shown in Figure 4.

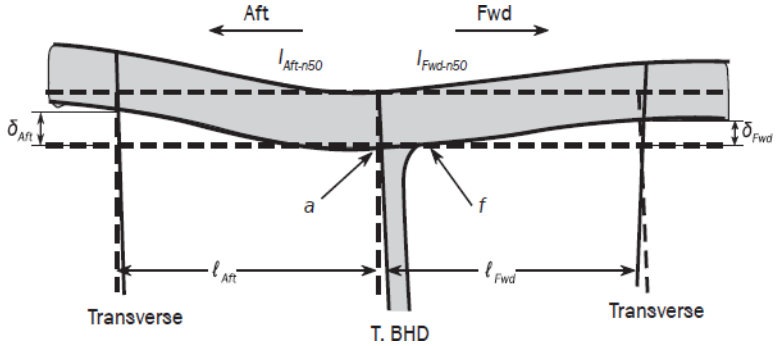


Figure 4 Definition of the relative displacement (example of the side longitudinal)

4.2.7 Stress due to relative displacement in still water

The additional hot spot stress, in N/mm^2, in still water, due to the relative displacement in the direction perpendicular to the attached plate between the transverse bulkhead including swash bulkhead or floor in way of stools and the adjacent transverse web or floor is to be obtained according to procedures of [4.2.4] and [4.2.5] for oil tankers and bulk carriers respectively, replacing dynamic local stress σ_{LD} and dynamic pressure with static local stress σ_{LS} and static pressure.

5 STRESS CONCENTRATION FACTORS

5.1 Unsymmetrical stiffener

5.1.1

The stress concentration factor K_n for unsymmetrical flange of built-up and rolled angle stiffeners under lateral load, calculated at the web's mid-thickness position, as shown in Figure 5, is to be taken as:

$$K_n = \frac{1+\lambda\beta^2}{1+\lambda\beta^2\psi_z}$$

where:

$$\lambda = \frac{3\left(1+\frac{\eta}{280}\right)}{1+\frac{\eta}{40}}$$

$$\eta = \frac{l_{bdg}^4 \cdot 10^{12}}{b_{f-n50}^3 \cdot t_{f-n50} \cdot h_{stf-n50}^2 \cdot \left(\frac{4 \cdot h_{stf-n50}}{t_{w-n50}^3} + \frac{s}{t_{p-n50}^3}\right)}$$

$$\beta = 1 - \frac{2b_{g-n50}}{b_{f-n50}} \quad \text{for built-up profiles}$$

$$\beta = 1 - \frac{t_{w-n50}}{b_{f-n50}} \quad \text{for rolled angle profiles.}$$

$b_{g\text{-}n50}$: Eccentricity of the stiffener equal to the distance from flange's edge to web's centreline, in mm, as shown in Figure 6.

$b_{f\text{-}n50}$: Net breadth of flange, in mm, as shown in Figure 6.

$t_{f\text{-}n50}$: Net flange thickness, in mm, as shown in Figure 6.

$h_{stf\text{-}n50}$: Net stiffener height, including face plate, in mm, as shown in Figure 6.

$t_{w\text{-}n50}$: Net web thickness, in mm, as shown in Figure 6.

$h_{w\text{-}n50}$: Net web's height stiffener, in mm, as shown in Figure 6.

$t_{p\text{-}n50}$: Net thickness of attached plating, in mm, as shown in Figure 6.

Ψ_z : Coefficient given as:

$$\psi_z = \frac{h_{w-n50}^2 t_{w-n50}}{4Z_{n50}} 10^{-3}$$

Z_{n50} : Net section modulus, in cm^3, of stiffener with an attached plating breadth equal to the stiffener spacing.

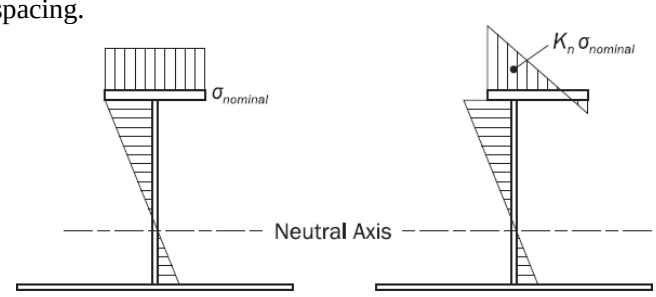


Figure 5 Bending stress in stiffener with symmetrical and unsymmetrical flange

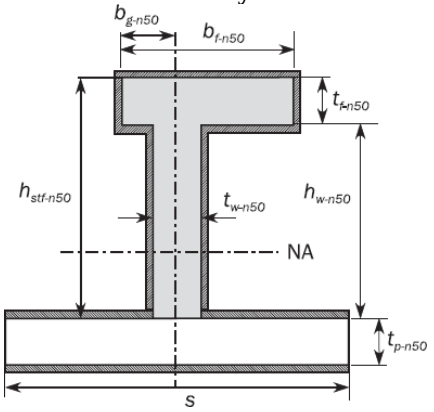


Figure 6 Stiffener - net scantling

5.1.2 Bulb profiles

For bulb profiles K_n factor is to be calculated using the equivalent built-up profile as shown in Figure 7. The flange of the equivalent built-up profile is to have the same properties as the bulb flange, i.e. same cross sectional area and moment of inertia about the vertical axis and neutral axis position. For HP bulb profiles, examples of the equivalent built up profile dimensions are listed in Table 3.

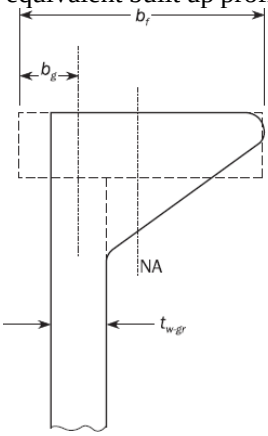


Figure 7 Bulb profile and equivalent built-up profile

HP equivalent built-up profile dimensions **Table 3**

HP-bulb		Equivalent built-up flange in gross thickness		
Height (mm)	Gross web thickness, $t_{w\text{-}gr}$ (mm)	b_f (mm)	$t_{f\text{-}gr}$ (mm)	b_g (mm)
200	9 – 13	$t_{w\text{-}gr}$ + 24.5	22.9	($t_{w\text{-}gr}$ + 0.9)/2
220	9 – 13	$t_{w\text{-}gr}$ + 27.6	25.4	($t_{w\text{-}gr}$ + 1.0)/2
240	10 – 14	$t_{w\text{-}gr}$ + 30.3	28.0	($t_{w\text{-}gr}$ + 1.1)/2
260	10 – 14	$t_{w\text{-}gr}$ + 33.0	30.6	($t_{w\text{-}gr}$ + 1.3)/2
280	10 – 14	$t_{w\text{-}gr}$ + 35.4	33.3	($t_{w\text{-}gr}$ + 1.4)/2
300	11 – 16	$t_{w\text{-}gr}$ + 38.4	35.9	($t_{w\text{-}gr}$ + 1.5)/2
320	11 – 16	$t_{w\text{-}gr}$ + 41.0	38.5	($t_{w\text{-}gr}$ + 1.6)/2
340	12 – 17	$t_{w\text{-}gr}$ + 43.3	41.3	($t_{w\text{-}gr}$ + 1.7)/2
370	13 – 19	$t_{w\text{-}gr}$ + 47.5	45.2	($t_{w\text{-}gr}$ + 1.9)/2
400	14 – 19	$t_{w\text{-}gr}$ + 51.7	49.1	($t_{w\text{-}gr}$ + 2.1)/2
430	15 – 21	$t_{w\text{-}gr}$ + 55.8	53.1	($t_{w\text{-}gr}$ + 2.3)/2

5.2 Longitudinal stiffener end connections

5.2.1

The stress concentration factors K_a and K_b are given in Table 4 for end connection of stiffeners subjected to axial and lateral loads. The values given in Table 4 for soft toe are valid provided the toe geometry complies with the requirements given in [5.2.5]. The stress concentration factor K_b given for lateral loads are to be used also for stress due to relative displacements.

5.2.2 Other connection types

When connection types other than those given in Table 4 are proposed, the fatigue strength for the proposed connection type is to be assessed either by performing a very fine mesh FE analysis as described in Ch 9, Sec 5 to obtain directly the hot spot stress, or by calculating the stress concentration factor using FE analysis according to [5.3].

5.2.3 Overlapped connection

Overlapped connection types for longitudinal stiffeners, i.e. attachments welded to the web of the longitudinals, are not to be used in the cargo hold region.

5.2.4 End stiffener without connection to web stiffener

Where the web stiffener is omitted or not connected to the longitudinal flange in way of:

- Side shell below 1.1 T_{sc}.
- Bottom.
- Inner hull longitudinal bulkhead below 1.1 T_{sc}.
- Hopper.
- Topside tank sloping plating below 1.1 T_{sc}.
- Inner bottom.

the following is required:

- A complete collar as defined in Figure 8 (i.e. connection type ID 31 of Table 4), or,
- A detail design for cut-outs as described in Ch 9, Sec 6, [2.1].

Equivalence to cut-outs given in Ch 9, Sec 6, [2.1] may be accepted provided it is assessed for fatigue by using comparative FE analysis which is based on hot spot stress around the cut-out in the web plate of the primary supporting member inclusive of the collar, as given in Ch 9, Sec 6, [2.2].

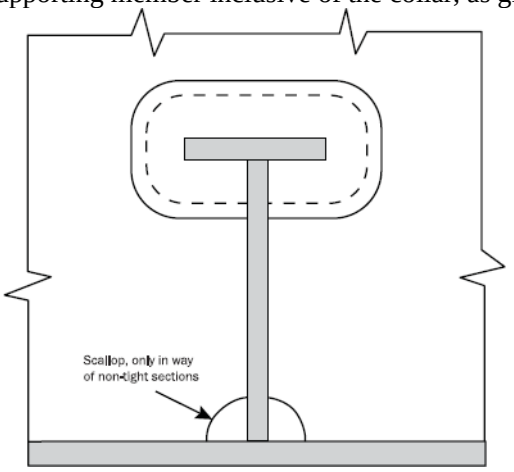


Figure 8 Complete collar

5.2.5 Soft toe of web stiffener and backing bracket

The toe geometry end connection of web stiffener and backing bracket is to comply with the following:

$\theta \leqslant 20$

$h_{toe} \leqslant \max(t_{bkt\text{-}gr}; 15)$

where:

θ : Angle of the toe, in deg, as shown in Figure 9.

h_{toe} : Height of the toe, in mm, as shown in Figure 9.

$t_{bkt\text{-}gr}$: Gross thickness of the bracket, in mm.

5.2.6 Recommended detail designs

Recommended detail designs for longitudinal end connections with soft toes and backing brackets are given in Figure 9.

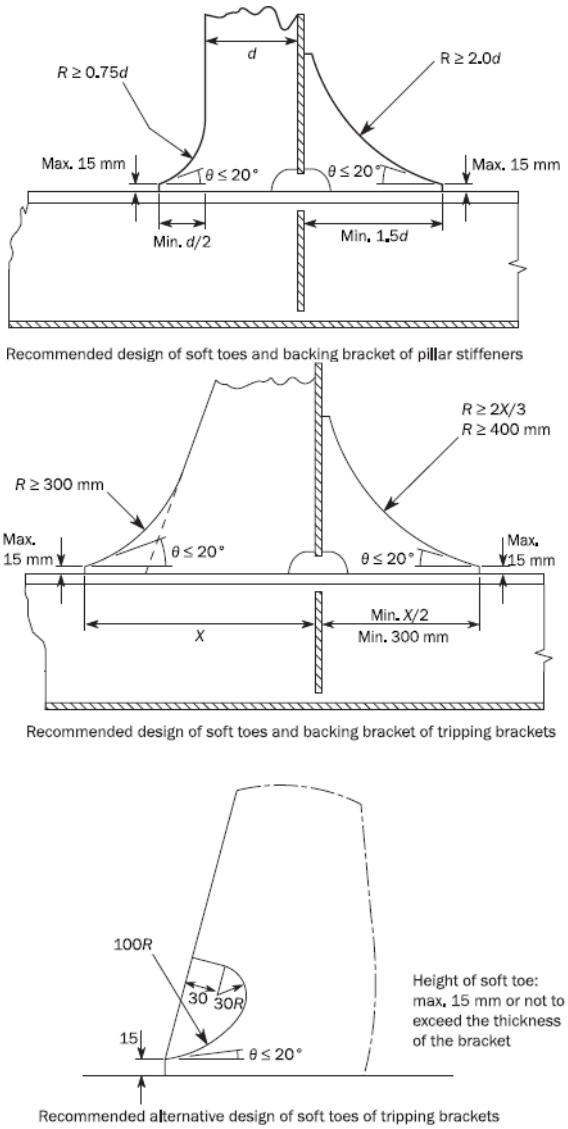
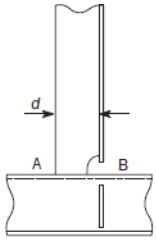
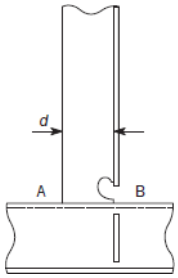
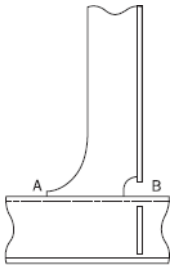
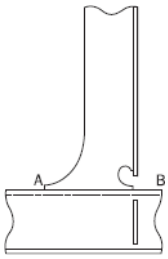
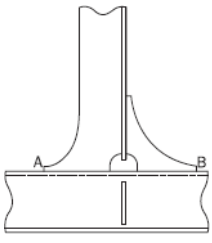
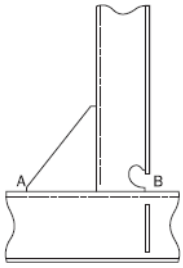
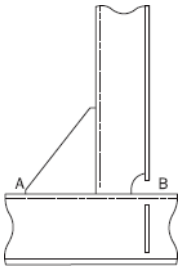
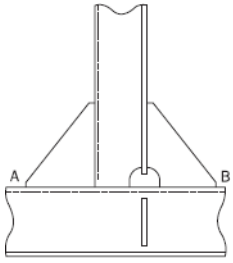
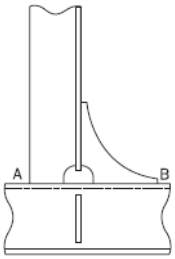
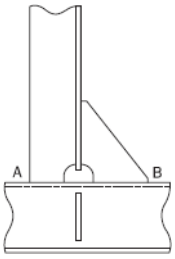
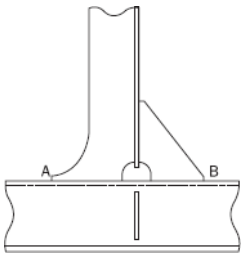
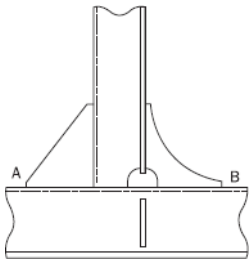
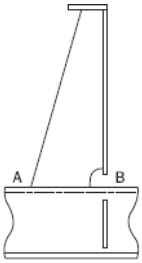
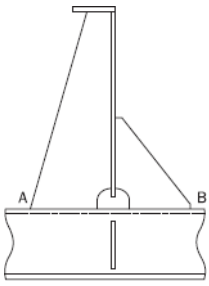
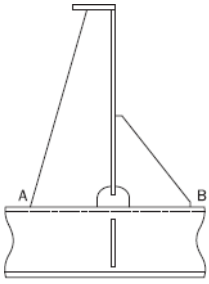
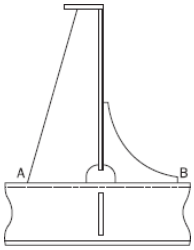
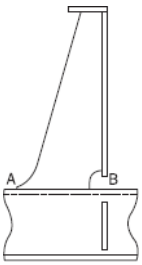


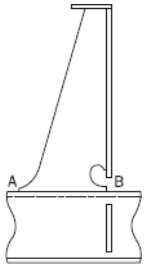
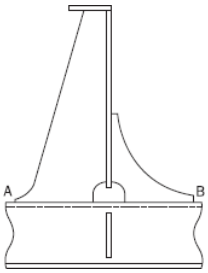
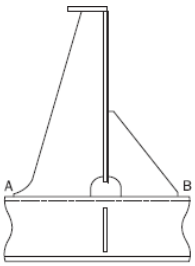
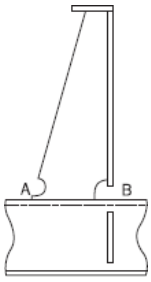
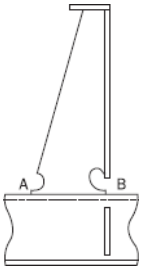
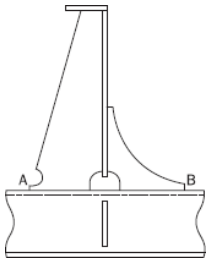
Figure 9 Detail design for soft toes and backing brackets

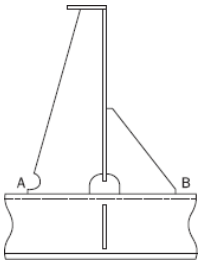
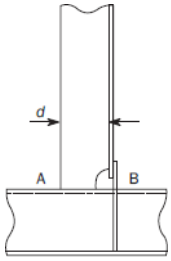
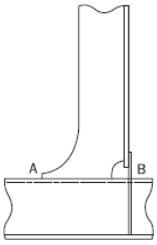
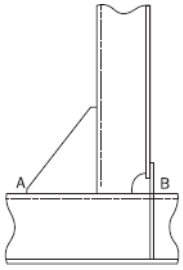
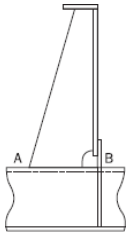
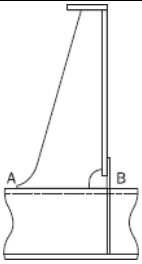
Stress concentration factors **Table 4**

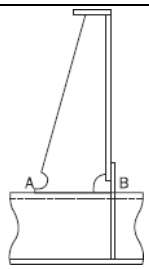
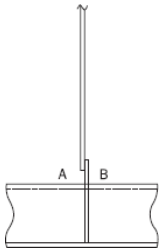
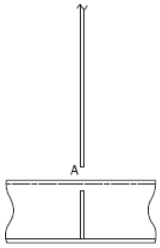
ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
1 [1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.60
2 [1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.14 for $d \leqslant 150$ 1.24 for $150 < d \leqslant 250$ 1.34 for $d > 250$	1.27
3		1.28	1.34	1.52	1.67
4		1.28	1.34	1.34	1.34
5		1.28	1.34	1.28	1.34

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
6		1.52	1.67	1.34	1.34
7		1.52	1.67	1.52	1.67
8		1.52	1.67	1.52	1.67
9		1.52	1.67	1.52	1.34
10		1.52	1.67	1.52	1.67
11		1.28	1.34	1.52	1.67

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
12		1.52	1.67	1.28	1.34
13		1.52	1.67	1.52	1.67
14		1.52	1.67	1.34	1.34
15		1.52	1.67	1.52	1.67
16		1.52	1.67	1.28	1.34
17		1.28	1.34	1.52	1.67

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
18		1.28	1.34	1.34	1.34
19		1.28	1.34	1.28	1.34
20		1.28	1.34	1.52	1.67
21		1.28	1.34	1.52	1.67
22		1.28	1.34	1.34	1.34
23		1.28	1.34	1.28	1.34

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
24		1.28	1.34	1.52	1.67
25[1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.14 for $d \leqslant 150$ 1.24 for $150 < d \leqslant 250$ 1.34 for $d > 250$	1.25 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.47 for $d > 250$
26		1.28	1.34	1.34	1.47
27		1.52	1.67	1.34	1.47
28		1.52	1.67	1.34	1.47
29		1.28	1.34	1.34	1.47

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
30		1.28	1.34	1.34	1.47
31 [4]		1.13	1.20	1.13	1.20
32 [4] [5] [6]		1.13	1.14	N/A	N/A

(1) The attachment length *d*, in mm, is defined as the length of the welded attachment on the longitudinal stiffener flange without deduction of scallop.
(2) Where the longitudinal stiffener is a flat bar and there is a web stiffener/bracket welded to the flat bar stiffener, the stress concentration factor listed in the table is to be multiplied by a factor of 1.12. when the thickness of attachment is thicker than the 0.7 times thickness of flat bar stiffener This also applies to unsymmetrical profiles where there is less than 8 mm clearance between the edge of the stiffener flange and the attachment, e.g. bulb or angle profiles where the clearance of 8 mm cannot be achieved.
(3) Designs with overlapped connection / attachments, see [5.2.3].
(4) ID 31 and 32 refer to details where web stiffeners are omitted or not connected to the longitudinal stiffener flange. See [5.2.4]
(5) For connection type ID 32 with no collar and/or web plate welded to the flange, the stress concentration factors provided in this table are to be used irrespective of slot configuration.
(6) The fatigue assessment point 'A' is located at the connection between the stiffener web and the transverse web frame or lug plate.

5.3 Alternative design

5.3.1 Derivation of alternative stress concentration factors

Upon agreement by the Society, the geometrical stress concentration factors for alternative designs are to be calculated by a very fine mesh FE analysis according to the requirements given in Ch 9, Sec 5. Additional requirements for derivation of geometrical stress concentration factors for stiffener end connections using very fine mesh FE analysis are given below:

a) FE model extent: the FE model, as shown in Figure 10, is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle frame. The same type of end connection is to be modelled at all the web frames. In the transverse direction, the model may be limited to one stiffener spacing.
b) Load application: in general, two loading cases are to be considered:
c) Axial loading by enforced displacement applied to the model ends and
d) Lateral loading by unit pressure load applied to the shell plating.
e) Boundary conditions:
f) Symmetry conditions are applied along the longitudinal cut of the plate flange, along

transverse and vertical cuts on web frames and on top of the web stiffener.

g) For lateral pressure loading: the model is to be fixed in all degrees of freedom at both forward and aft ends.

h) For axial loading: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa.

i) FE mesh density: At the location of the hot spots under consideration, the element size is to be in the order of the thickness of the stiffener flange. or 10mm depending on the type of stiffener In the remaining part of the model, the element size is to be in the order of s/10, where s is the stiffener spacing.

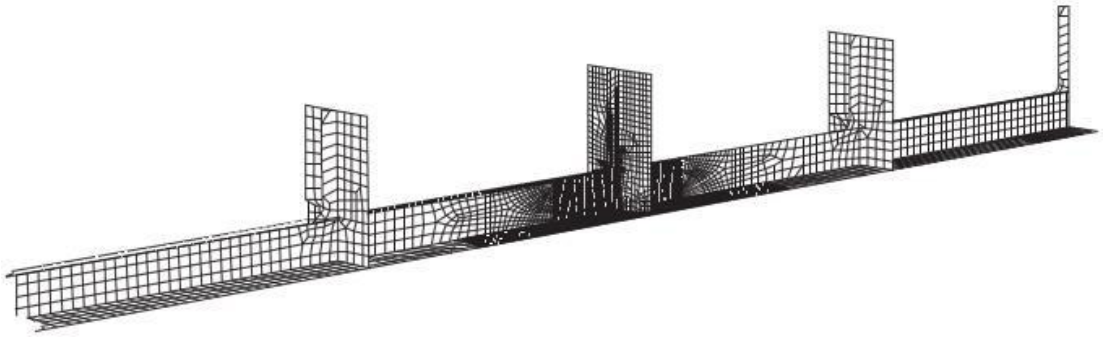


Figure 10 Fine mesh finite element model for derivation of geometrical stress concentration factor(example of stiffener with flange)

For the 2 loading cases specified above, the stress concentration factors are determined as follows:

- For the axial loading case:

$$K_a = \frac{\sigma_{HSAx}}{\sigma_{NomAx}}$$

- For the bending loading case:

$$K_b = \frac{\sigma_{HSBd}}{\sigma_{NomBd}}$$

σ_{HSAx} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the axial load.

σ_{NomAx}: Nominal axial stress, in N/mm^2, calculated at the stiffener flange according to [3.1] for the axial load applied for the FE calculation.

σ_{HSBd} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the unit pressure load.

σ_{NomBd}: Nominal bending stress, in N/mm^2, calculated at the stiffener flange according to [4.1] in way of the hot spot for the unit pressure load applied for the FE calculation.

The derivation of geometrical stress concentration factors for alternative designs is to be documented and provided to the Society.

ISC 5.3.1a FE model extent

(1) FE model extent

The FE model, as shown in Figure ISC 5.3.1a(1), is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle web frame. The same type of end connection is to be modeled at all the web frames. In the transverse direction, the model is to cover at least half the stiffener spacing on both sides; in the vertical direction, it is to maintain at least half the web height.

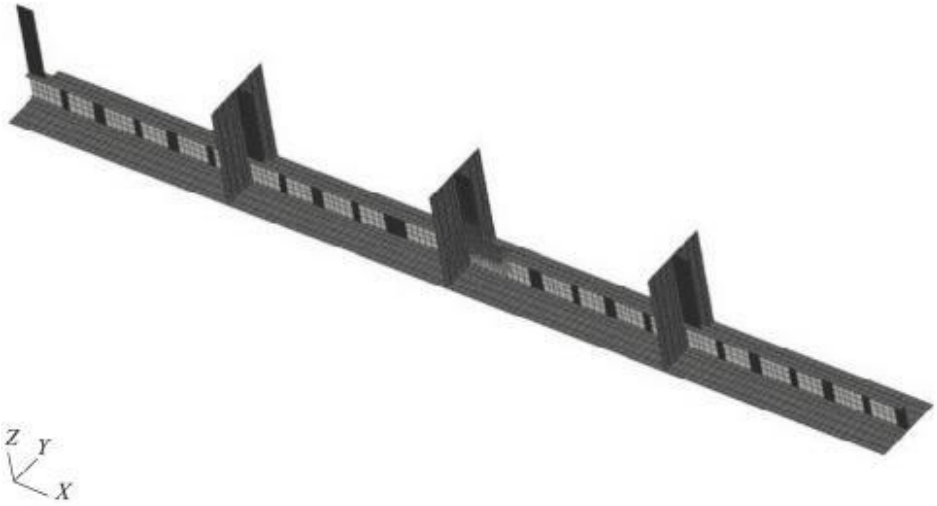


Figure ISC 5.3.1a(1) Longitudinal Extent of Fine Mesh Finite Element Model

(2) FE mesh size

At the location of the hot spots under consideration, the mesh size of at least 10 elements is to be the same as the thickness of the flange of longitudinals. In the remaining part of the model, the mesh size is to be taken as1/10 of the spacing of longitudinals. Attention is to be given to the smooth transition of mesh size. It is recommended to use mm as the length unit during modeling.

(3) Load case

Axial load case: enforced displacement of 1 mm applied to the model ends.

Lateral load case: uniformly distributed unit load applied to the attached plating of longitudinal, in 1 kN/m^2, i.e. 0.001 Mpa.

(4) Boundary conditions

Symmetry conditions:

a) *angular displacement $\theta_x = 0$, displacement $\delta_y = 0$ along the longitudinal edge of the attached plate, see Figure ISC 5.3.1a(2);*
b) *angular displacement $\theta_z = 0$, displacement $\delta_y = 0$ along vertical edge on web frames, see Figure ISC 5.3.1a(3);*
c) *angular displacement $\theta_y = 0$, displacement $\delta_z = 0$ along transverse edge on top of web frames, see Figure ISC 5.3.1a(4);*
d) *angular displacement $\theta_x = 0$, displacement $\delta_z = 0$ on top of the web stiffener, see Figure ISC 5.3.1a(5).*

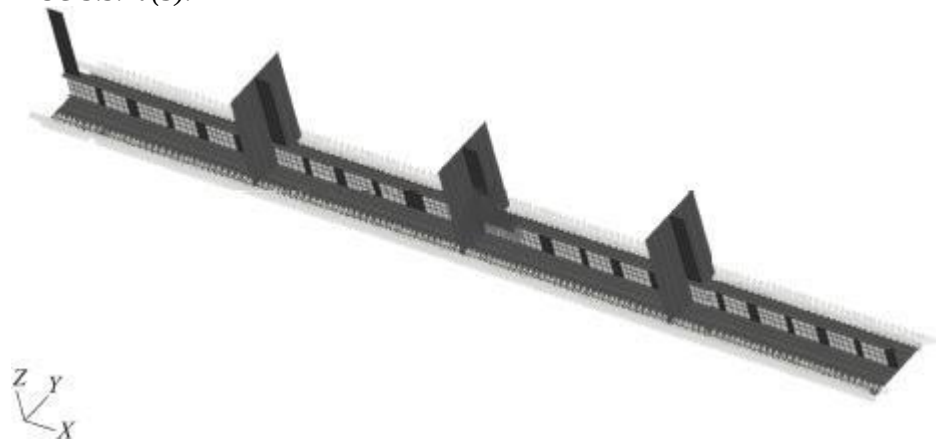


Figure ISC 5.3.1a(2) Boundary Condition of Fine Mesh Finite Element Model (a)

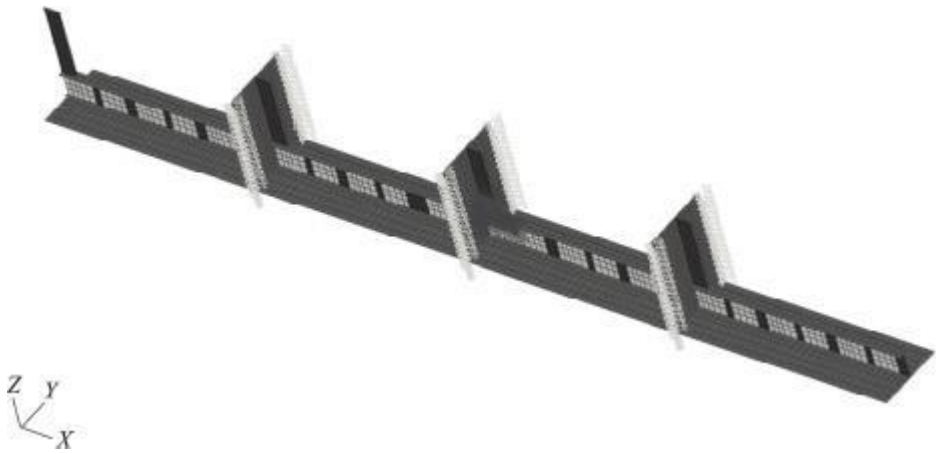


Figure ISC 5.3.1a(3) Boundary Conditions of Fine Mesh Finite Element Model(b)

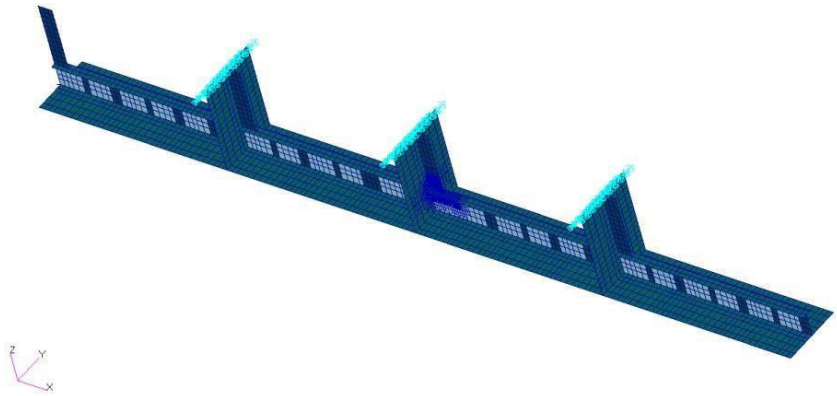


Figure ISC 5.3.1a(4) Boundary Conditions of Fine Mesh Finite Element Model(c)

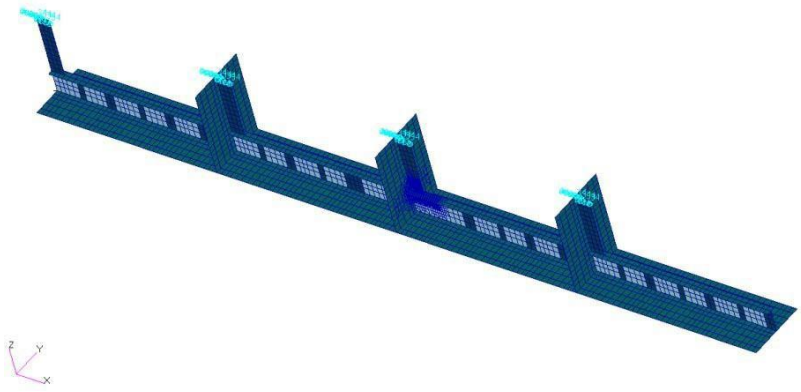


Figure ISC 5.3.1a(5) Boundary Conditions of Fine Mesh Finite Element Model (d)

For axial load case: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa. For lateral load case: the model is to be fixed in all degrees of freedom at both forward and aft ends.

ISC 5.3.1b Calculation of stress concentration factors

(1) The geometrical stress concentration factor, K_g , is calculated in accordance with the following formula:

$$K_g = \frac{\sigma_{HS}}{\sigma_{nom}}$$

where:

σ_{HS} : hot spot stress, in N/mm^2, to be calculated in accordance with (2) of this paragraph;

σ_{nom}: nominal stress, in N/mm^2, to be calculated in accordance with (3) of this paragraph and taken as σ_{axial} or $\sigma_{lateral}$.

(2) Hot spot stress σ_{HS} , in N/mm^2, is calculated in accordance with the following formula according to the process as specified in 3.1, Section 5 of Chapter 9:

$$\sigma_{HS} = 1.12\sigma$$

where:

σ : longitudinal stress obtained from interpolation of FE calculation, in N/mm^2.

(3) Calculation of nominal stress

a) The nominal stress σ_{axial} , in N/mm^2, of axial load case is calculated in accordance with the following formula:

$$\sigma_{axial} = \frac{\Delta l}{l} E$$

where:

Δl: axial enforced displacement, in mm;

l : length of FE model, in mm;

E : Young's modulus of elasticity, 2.06×10^5 N/mm^2.

b) The nominal stress $\sigma_{lateral}$, in N/mm^2, of bending load case under lateral load is calculated in accordance with the following formula:

$$\sigma_{lateral} = \frac{sl^2(1-\frac{6x_e}{l}+\frac{6x_e^2}{l^2})}{12Z_{eff-n50}}10^3$$

where:

s : spacing of longitudinals, in m;

l : full length, in m, see definition of l in Symbols of Section 7, Chapter 3;

$Z_{eff\text{-}n50}$:section modulus, in cm^3,deducting corrosion addition of $0.5t_c$ and considering attached plating;

x_e :distance, in m, from the hot spot to the closest end of full length l.

Section 5 FINITE ELEMENT STRESS ANALYSIS

1 GENERAL

1.1 Applicability

1.1.1

This section applies to fatigue assessment by finite element stress analysis. The methods are based on the hot spot stress approach and requirements are given for both welded and non-welded hot spots. The hot spot stress takes into account structural discontinuities due to the structural detail of the welded joint, but not taking into account the notch effect at the weld toe.

1.1.2

The hot spot stress is generally highly dependent on the finite element model used for representation of the structure and the procedure used to calculate the hot spot stress. No other methods than those described in this Section is to be adopted for calculation of FE based hot spot stress.

1.1.3

Two types of hot spots, denoted '*a*' and '*b*' are described in Table 1. These are defined according to their location on the plate and their orientation to the weld toe as illustrated in Figure 1.

Types of hot spots **Table 1**

Type	Description
a	Hot spot at the weld toe on plate surface
b	Hot spot at the weld toe around the plate edge

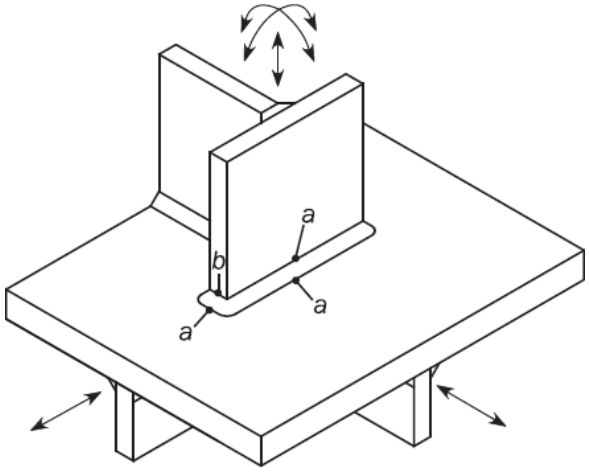


Figure 1 Types of hot spots

1.1.4

The method for calculation of hot spot stress at weld toe for any welded details is given in [3.1] except for web- stiffened cruciform joints. The method for calculation of local stress for non-welded area is given in [3.2].

1.1.5

The method for calculation of hot spot stress at web-stiffened cruciform joints such as hopper knuckle connection, transverse bulkhead lower stool to inner bottom connection and horizontal stringer heel is given in [4].

1.1.6

Attention is to be given to limitations of the hot spot stress methodology for simple connections given in [5].

2 FE MODELLING

2.1 General

2.1.1

Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. These very fine mesh zones may be incorporated into the global model as shown in Figure 2. The coarse mesh model of the cargo holds is to be made according to Ch 7, Sec 2, [2.4]. Alternatively, this very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a global model of the cargo holds. Typical local finite element models of a hopper knuckle with very fine mesh are shown in Figure 3, Figure 4, and Figure 5.

2.1.2 Corrosion model

The very fine mesh finite element models used for fatigue assessment are to be made using net thickness, t_{n50}, in accordance with Ch 9, Sec 1, [5.1].

2.1.3 Separate local FE model

Where a separate local finite element model is used, the extent of the local model is to be such that the calculated stresses are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to be taken at adjacent primary supporting members such as girders, stringers and floors in the cargo hold model as far as practicable. Transverse web frames, stringer plates and girders at the boundaries of the local model need not be represented in the local model.

2.1.4

The evaluation of hot spot stress for '*a*' type hot spot is to be based on shell element of mesh size t_{n50}, $\times t_{n50}$, where t_{n50}, is the net thickness of the plate in way of the considered hot spot. The evaluation of hot spot stress for a '*b*' type hot spot is to be based on shell element of mesh size 10×10 mm. The aforementioned mesh size is to be maintained within the very fine mesh zone, extending over at least 10 elements in all directions from the fatigue hot spot position. The transition of element size between the coarser mesh and the very fine mesh zone is to be done gradually and an acceptable mesh quality is to be maintained. This transition mesh is to be such that a uniform mesh with regular shape gradually transitions from smaller elements to larger ones. An example of the mesh transition in way of the side frame bracket toe is shown in Figure 6.

2.1.5

Four-node shell elements with adequate bending and membrane properties are to be used inside the very fine mesh zone. The four node element is to have a complete linear field of in-plane stresses and hence pure in- plane bending of the element can be exactly represented. In case of steep stress gradients, 8 node thin shell elements are to be used if deemed practical. The shell elements are to represent the mid plane of the plating. For practical purposes, adjoining plates of different thickness may be assumed to be median line aligned, i.e. no staggering in way of thickness change is required. The geometry of the weld and construction misalignment is not required to be modelled.

2.1.6

All structure in close proximity to the very fine mesh zones is to be modelled explicitly with shell elements. Triangular elements are to be avoided where possible. Use of extreme aspect ratio (e.g. aspect ratio greater than 3) and distorted elements (e.g. element's corner angle less than 60 deg or greater than 120 deg) are to be avoided.

2.1.7

Where stresses are to be evaluated on a free edge, such as cut-outs for stiffener connections at web frames, edge of plating and hatch corners, beam elements having the same depth as the adjoining plate thickness and negligible width is to be used to obtain the required local edge stress values.

2.2 Hopper knuckle welded connection

2.2.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of bilge hopper lower-knuckle and upper-knuckle welded connections.

2.2.2
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the transverse web frame of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the baseline to the lower stringer in the double side water ballast tank for tankers and double skin bulk carriers. For single skin bulk carriers, the model is to extend from the baseline to the top of the hopper ballast tank. Where a fatigue assessment is also carried out for the upper knuckle connection, the model is to be extended to four longitudinal spaces above the lower stringer in the double side ballast tank.
c) Transversely, for the hopper lower knuckle, the model is to extend from the ship side to 4 longitudinal spaces inboard of the double bottom side girder. For the upper hopper knuckle, the model is to extend from the ship side to the double bottom side girder.

2.2.3
Any scarfing brackets on the web frame adjoining the inner bottom plating, the first longitudinal stiffeners away from the knuckle hot spot as well as any carlings and brackets offset from the main frames are to be modelled explicitly using shell elements. Longitudinal stiffeners further away from the knuckle may be modelled by beam elements. The inner bottom plate 'overhang' outboard of the girder is to be modelled using shell elements up to the extent of the scarfing bracket. Away from the scarfing bracket in longitudinal direction, the inner bottom plate 'overhang' may be modelled using line elements of equivalent the area. Any perforations, such as cut-outs for cabling, pipes and access that are within one stiffener space from the knuckle point are to be modelled explicitly.

2.2.4
Figure 3, Figure 4 and Figure 5 show typical local finite element models of the hopper knuckle connection and close-up views of the $t_{n50} \times t_{n50}$ mesh zone.

2.3 Horizontal stringer heel connection

2.3.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of horizontal stringer heel connections.

2.3.2
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover one web frame space away from the stringer heel to at least one web frame space ahead of the stringer toe. Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend at least to the next stringer level above and below the concerned stringer heel location.
c) Transversely, the model is to extend from the ship side to a half of the tank width in case of a stringer heel located at the inner hull longitudinal bulkhead. In case of stringer heel located at other longitudinal bulkheads the model is to extend transversely up to half the tank width on either side of the concerned stringer heel.

2.3.3
Shell elements are to be used for modelling the stringer heel connection and adjacent stiffeners. The first longitudinal and vertical stiffeners away from the heel hot spot are to be modelled explicitly using shell elements. Longitudinal and vertical stiffeners further away from the hot spot

may be modelled by beam elements. Figure 7 shows a typical finite element model of the stringer heel connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.4 Lower stool – inner bottom connection

2.4.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and inner bottom plate.

2.4.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom shell to a level at least 2 m above the inner bottom or up to the connection of the corrugation to the upper shelf plate of the lower stool, whichever is greater.
b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.
c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.4.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms and brackets. The first vertical or horizontal stiffeners on the lower stool plate and the first longitudinal stiffeners on the inner bottom are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 8 shows a typical finite element model of the lower stool - inner bottom connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.3 Lower stool – corrugated bulkhead connection

2.5.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and corrugated bulkhead.

2.5.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom of the lower stool to a level at least 2 m above the upper shelf plate of the lower stool.
b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.
c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.5.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms, and bracket. The first vertical or horizontal stiffeners on the lower stool plate are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 9 shows a typical finite element model of the lower stool - corrugated bulkhead connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.4 Side frame bracket to hopper sloping plate connections

2.6.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame to hopper sloping plate bracket connections.

2.6.2
Shell elements are to be used for modelling the side frame bracket, hopper tank sloping plate and adjacent stiffeners. Figure 10 shows a typical finite element model of the side frame bracket to hopper sloping plate connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.6.3
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the baseline to the bottom of the topside tank sloping plate.
c) Transversely, the model is to extend from the ship side to the adjacent double bottom side girder.

2.5 Side frame bracket to the upper sloping / flat bottom wing tank connections
2.7.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame bracket to upper sloping/flat bottom wing tank connections.

2.7.2
Shell elements are to be used for modelling the side frame bracket, upper sloping or flat bottom plate and adjacent stiffeners. Figure 11 shows a typical finite element model of the side frame bracket to upper sloping wing tank with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.7.3
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the deck level to the top of the hopper sloping plate.
c) Transversely, the model is to extend from the ship side to the end of upper sloping/flat bottom wing tank.

2.6 Hatch corners and hatch coaming end bracket
2.8.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of hatch corners/hatch coaming end bracket. The selection of hatch corners / hatch coaming end bracket for fatigue analysis is to be determined based on the level of stresses obtained from the cargo hold FE analysis.

2.8.2
Where separate local finite element models are used, the model extents are to be according to the following:

a) Transversely, over the half-breadth of the ship,
b) Longitudinally, from the midpoint of the cargo hold in which the concerned hatch corners/hatch coaming end bracket is located to the adjacent cargo hold up to and including the full width of the cross deck nearest to the concerned hatch corners/hatch coaming end bracket.
c) Vertically, from the top plate of coaming to the intersection of the topside tank sloping plate with the side or inner side shell.

2.8.3
The primary supporting members and coaming stays are to be represented by shell finite elements having both membrane and bending properties. Figure 12 shows a typical FE model of the toe connection of a longitudinal hatch coaming end bracket to the deck plating with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.8.4
The level of FE mesh refinement is to be such as to enable stress concentrations arising from the hatch corner geometry to be captured in the hot spot stress. The plate edge of hatch opening corners at the level of upper deck and cross deck structure is to be assessed. The free edge of hatch coaming end bracket and bracket toe welded connection to the deck plating are also to be assessed. Beam elements having the same depth as the adjoining plate thickness and negligible width are to be used at a plate edge of hatch opening corners or free edge of the hatch coaming end bracket to obtain the required local edge stress values as outlined in [2.1.7].

2.8.5
The local structural geometry, particularly in the areas of concern, is to be represented. The hatch corner area is to be meshed using elements with a sufficiently small size to capture the local stress on the edge. In general, a minimum of 15 elements in a 90 degree arc are to be used to describe the curvature of the hatchway radius plating for a rounded corner (see Figure 13). For an elliptical or parabolic corner, a minimum of 15 elements are to be used from the inboard radius end to a point on the edge located at half the longitudinal distance of the semi- major axis. A total of 20 elements are to be used at the elliptical edge of the hatch corner (see Figure 14). However, the element edge dimensions along the free edge of the radius need not be less than the thickness of the plating being represented and also should not be greater than 5 times the thickness of the plating being represented. Except where necessary from practical meshing considerations, this level of idealisation is to be maintained over the bracket plating and is to extend into the stringer plating, deck plating and coaming. Mesh transitions should not be arranged close to bracket toes.

2.7 Boundary conditions

2.7.7 Cargo hold model
The boundary conditions to be applied to the ends of the cargo hold model are to be in accordance with Ch 7, Sec 2, [2.5].

2.7.8 Separate local finite element model
Where a separate local finite element model is used for evaluating the hot spot stress range, the boundary conditions and application of loads are to be in accordance with Ch 7, Sec 3, [4.2].

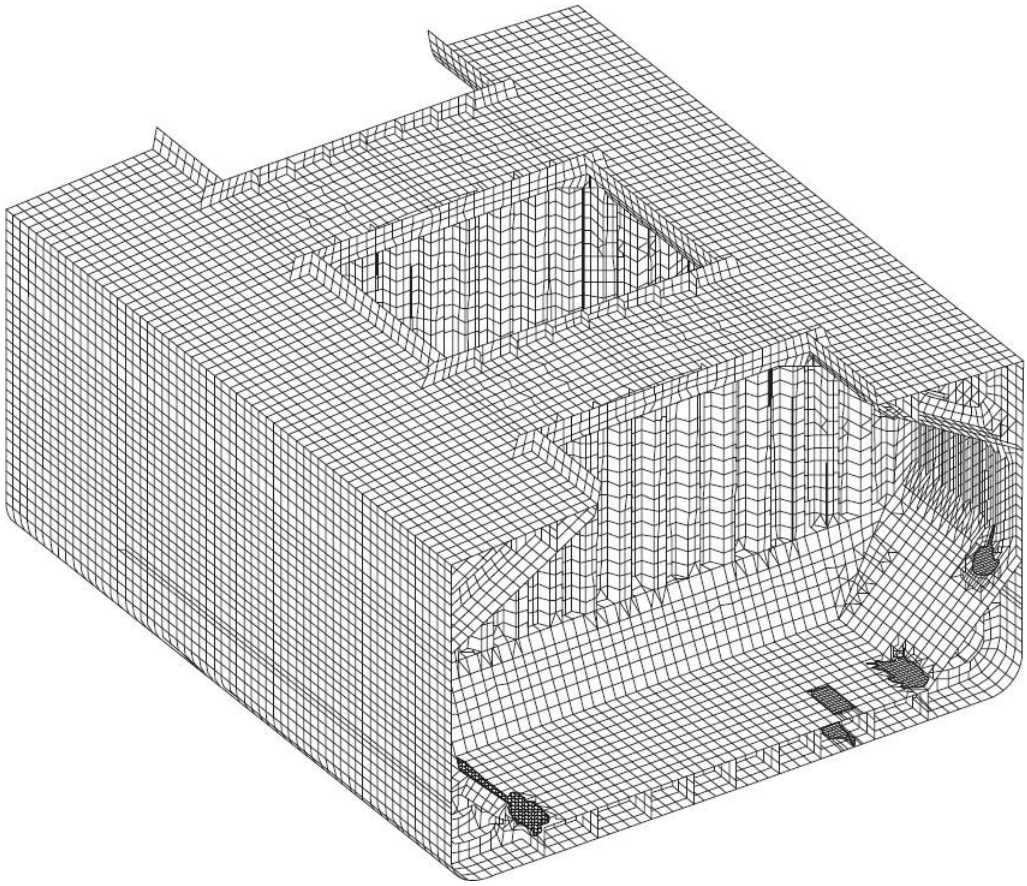


Figure 2 Very fine mesh areas incorporated

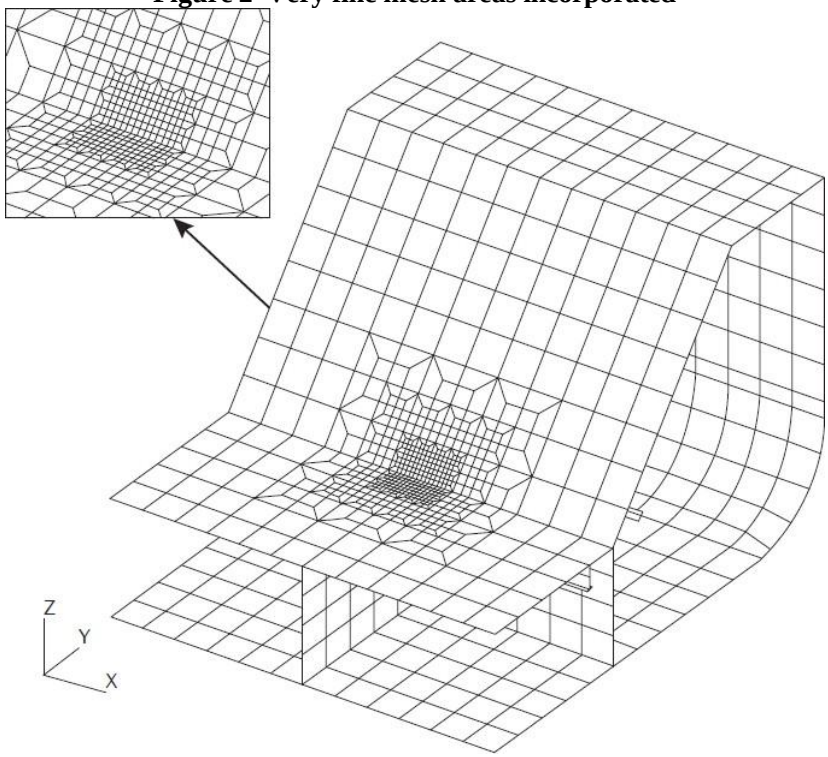


Figure 3 Local very fine mesh model (t_{n50}×t_{n50}) of hopper knuckle connection between inner bottom and hopper plate

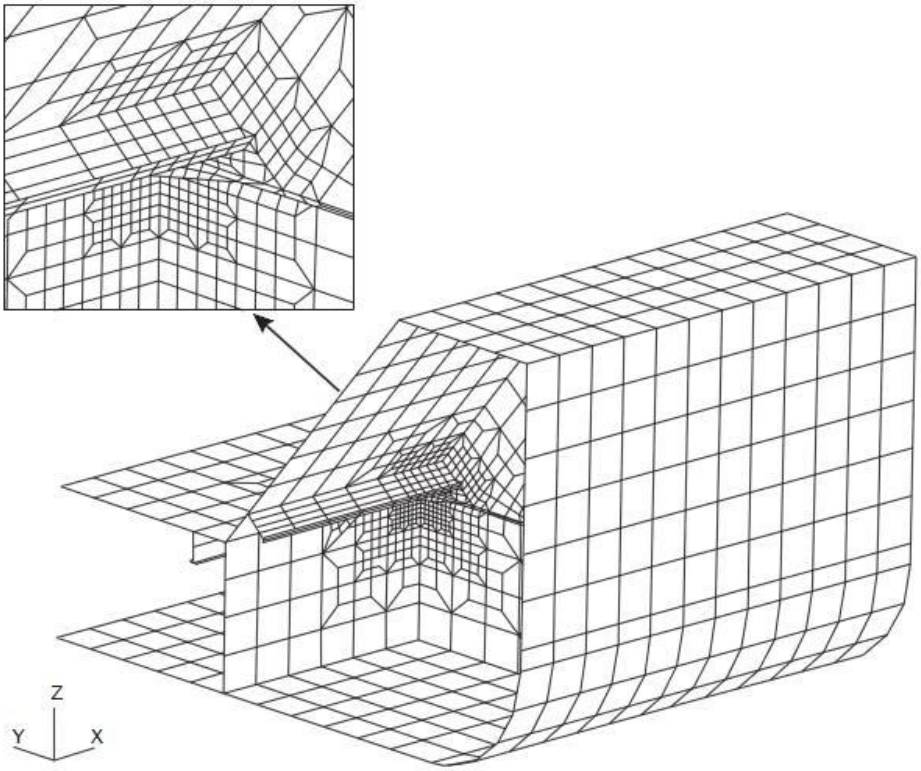


Figure 4 Local very fine mesh model (t_{n50}×t_{n50}) of hopper knuckle connection between inner bottom, hopper plate, web frame, girder and bracket

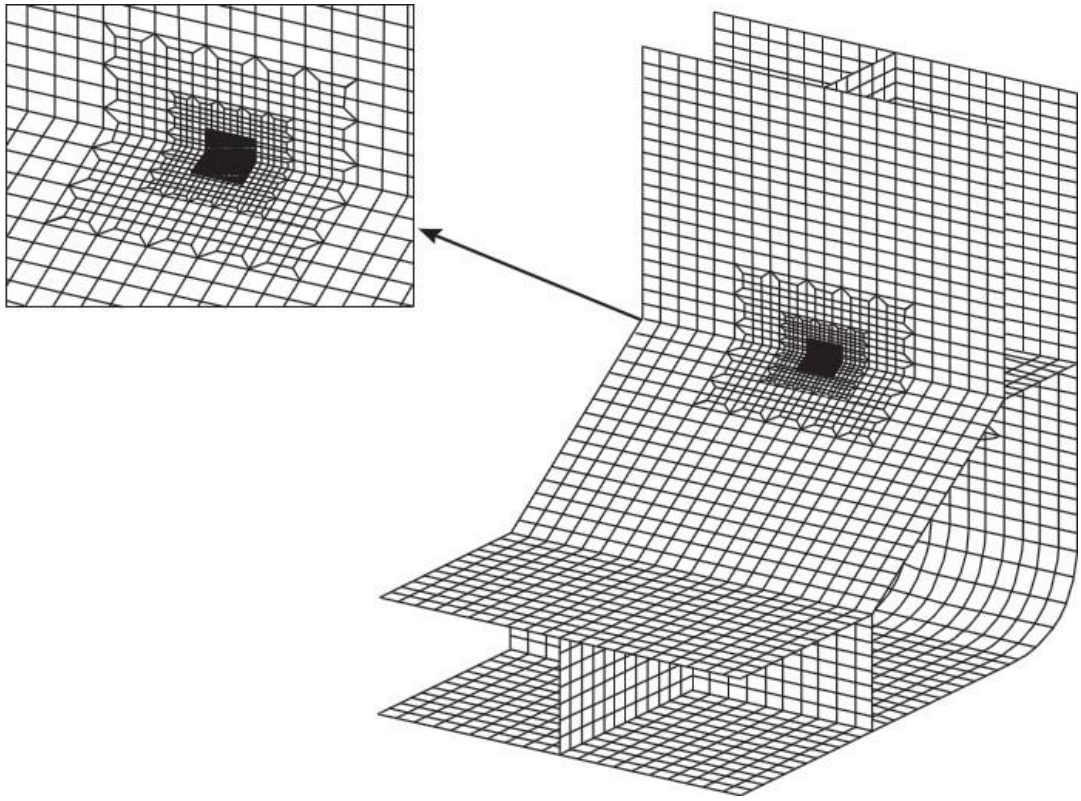


Figure 5 Local very fine mesh model (t_{n50}×t_{n50}) of upper hopper knuckle connection between inner side shell and hopper plate

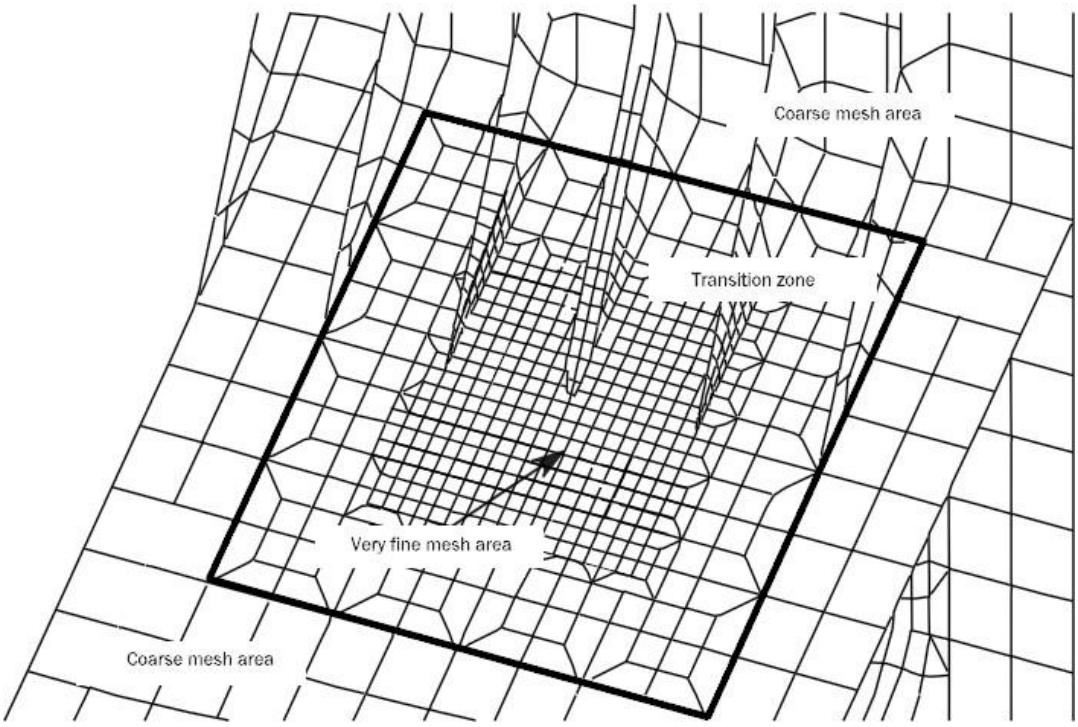


Figure 6 Transition area between coarse and very fine mesh

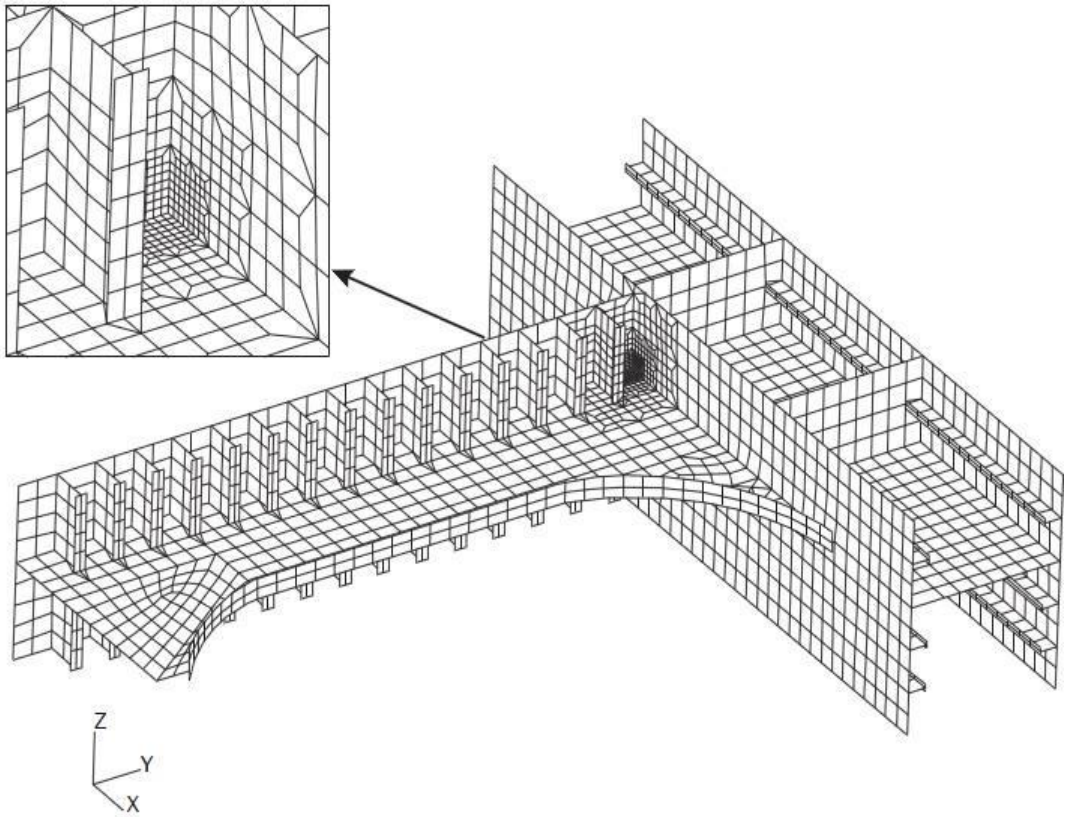


Figure 7 Finite element model of stringer heel connection

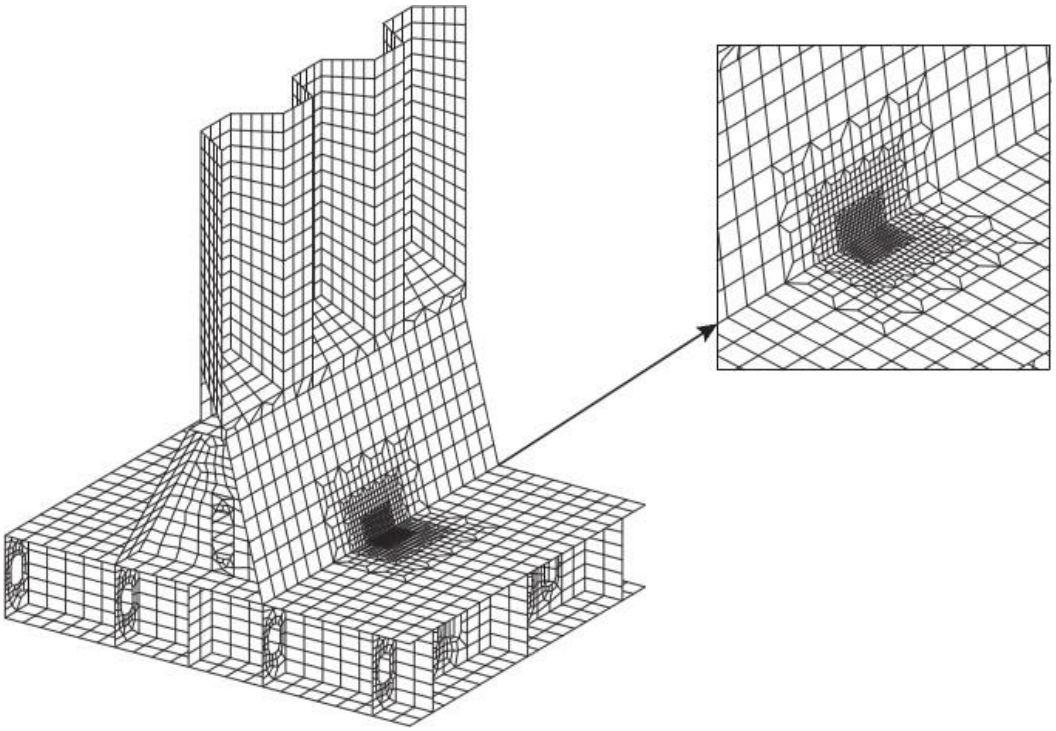


Figure 8 Local FE model of lower stool connection between inner bottom and lower stool plate, $t_{n50} \times t_{n50}$ mesh

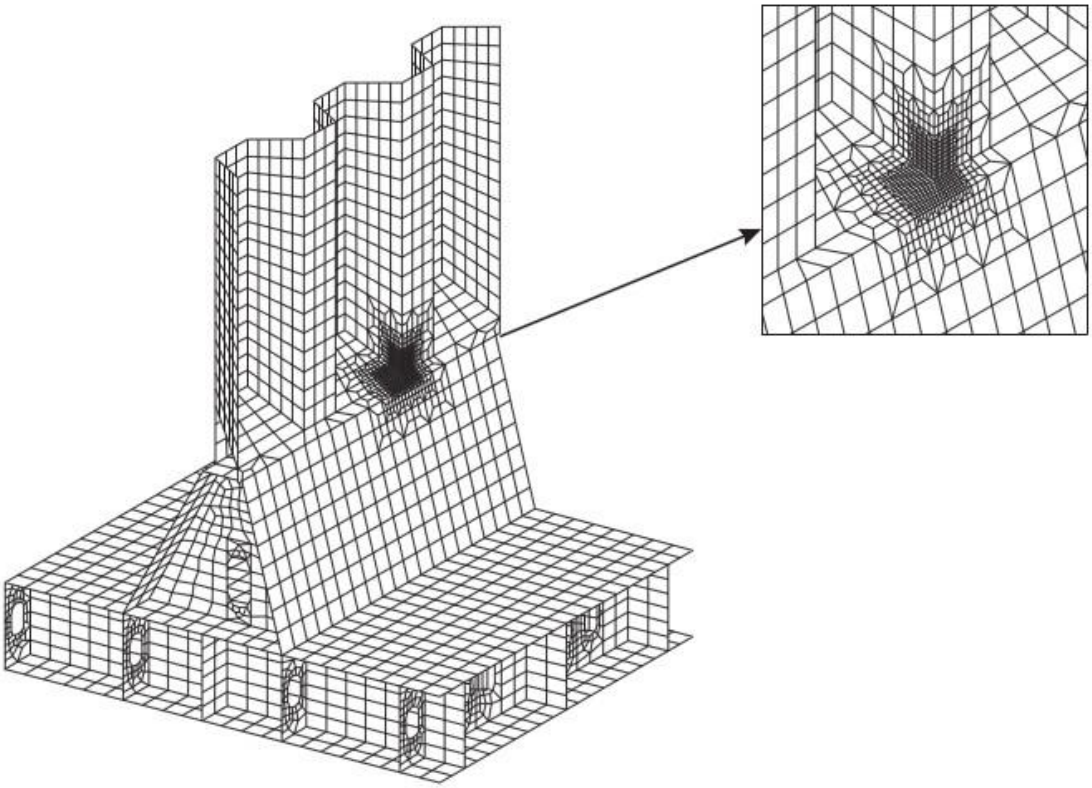


Figure 9 Local finite element model of lower stool - corrugated bulkhead connection between corrugated bulkhead and lower stool plate, $t_{n50} \times t_{n50}$ mesh

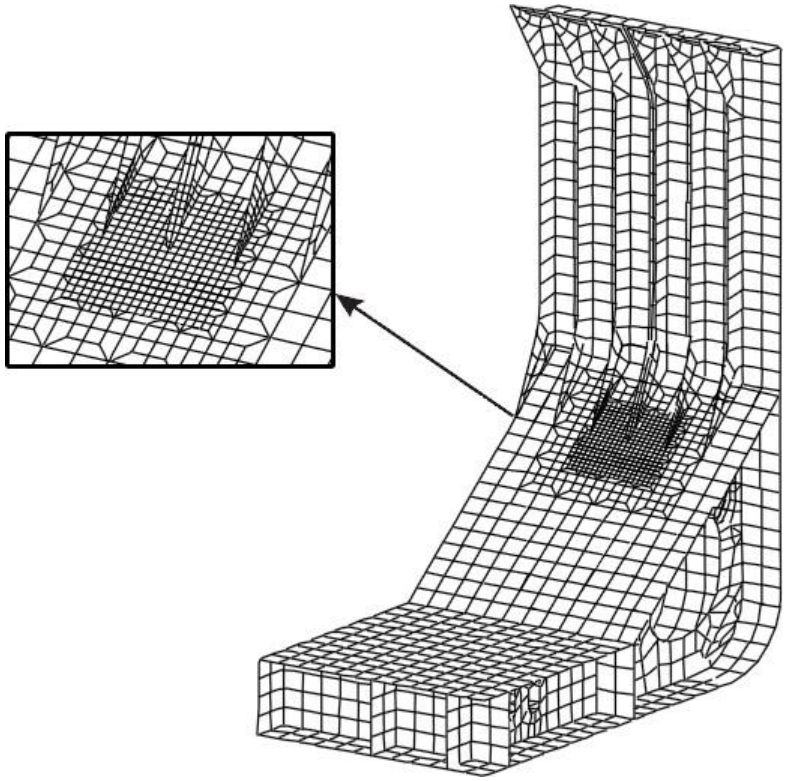


Figure 10 Local finite element model of side frame bracket, t_{n50}×t_{n50} mesh

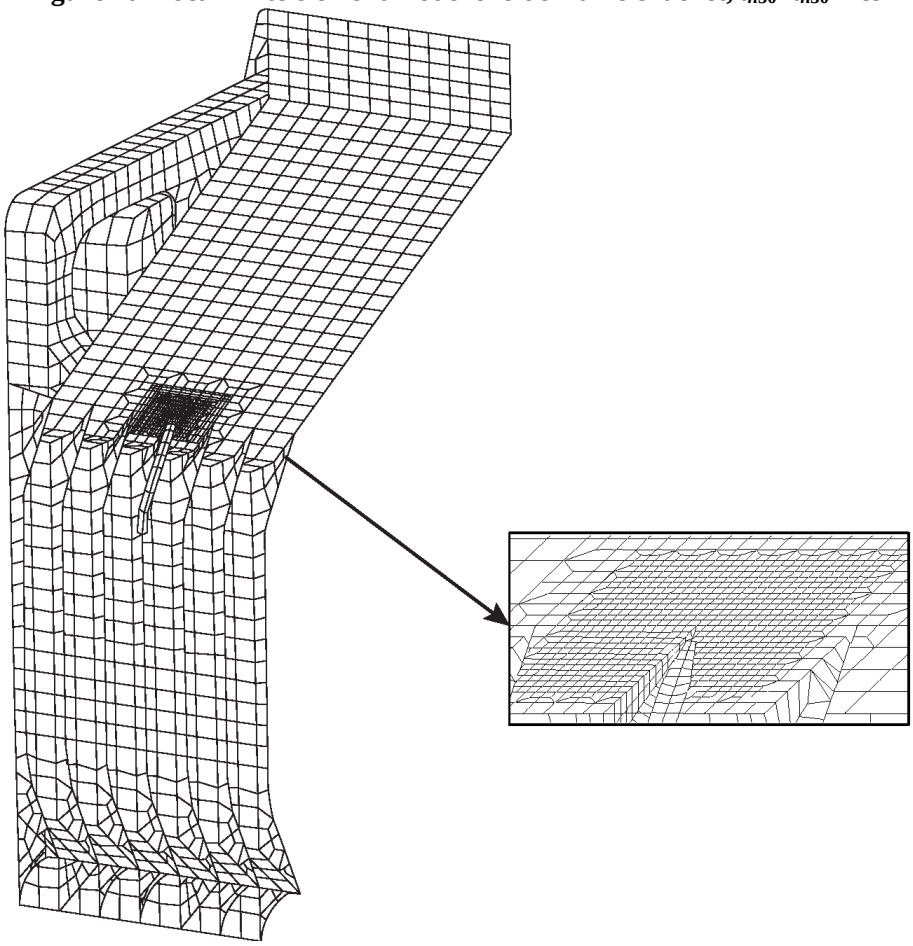


Figure 11 Local FE modelof upper side frame bracket t_{n50}×t_{n50} mesh

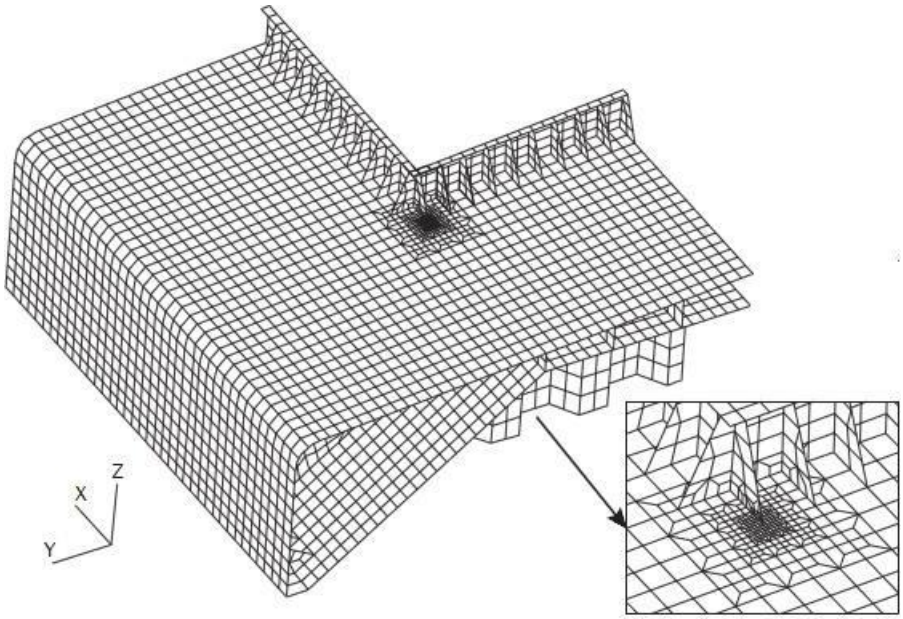


Figure 12 Local FE model of longitudinal hatch coaming end bracket to the deck plating with very fine mesh zone, $t_{n50} \times t_{n50}$ mesh

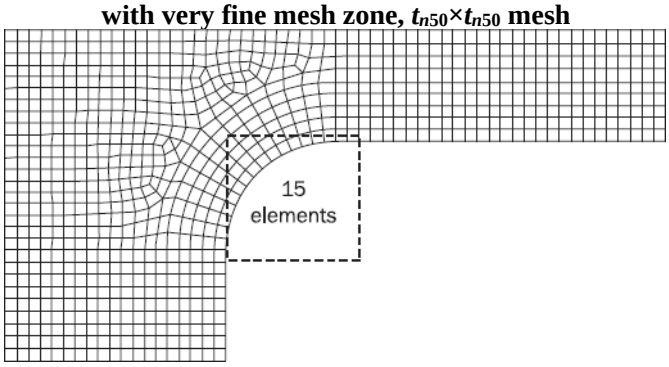


Figure 13 Mesh density for rounded hatch corner

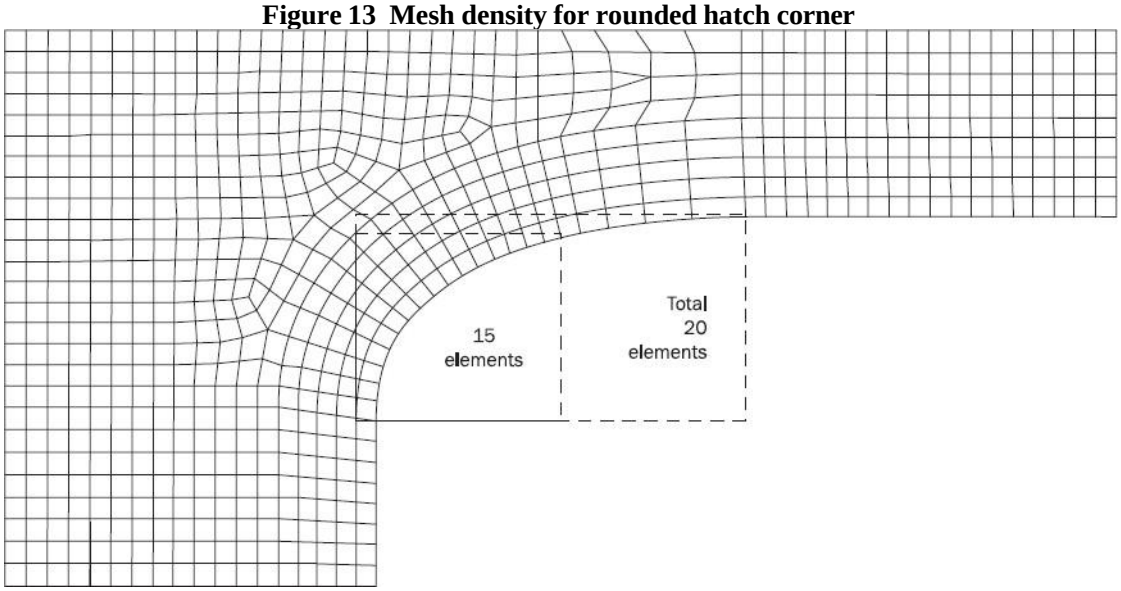


Figure 14 Mesh density for elliptical hatch corner

3 HOT SPOT STRESS FOR DETAILS DIFFERENT FROM WEB-STIFFENED CRUCIFORM JOINTS

3.1 Welded details

3.1.1

For hot spot type '*a*', the structural hot spot stress, σ_{HS} is calculated from a finite element analysis

with $t_{n50} \times t_{n50}$ mesh density and is obtained by the following formula:
$\sigma_{HS} = 1.12\ \sigma$
where:
σ : Surface principal stress, in N/mm^2, read out at a distance $t_{n50}/2$ away from the intersection line.
t_{n50} *:* Plate net thickness, in mm, in way of the weld toe.
At structural details where the hot spot type '*a*' is classified as a web-stiffened cruciform joint, the stress read out procedure of [4.2] is to be applied.
For hot spot type '*b*', the stress distribution is not dependent on the plate thickness; the structural hot spot stress, σ_{HS}, is derived from a finite element analysis with mesh density 10×10 mm and is obtained by the following formula:
$\sigma_{HS} = 1.12\ \sigma$
where:
σ : Surface principal stress, in N/mm^2, read out at an absolute distance from the intersection line of 5 mm.

3.1.2 Stress read out methods

Depending on the element type, one of the following stress read out method is to be used:

- With 4-node shell element:
  Element surface stress components at the centre points are linearly extrapolated to the line A-A as shown in Figure 15 to determine the stress components for load case '*i*1' and '*i*2' at the stress read out point located at a distance t_{n50} from the intersection line for type 'a' hot spot. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor differences (between load case '*i*1' and '*i*2') calculated from each side (side L, side R) of line A-A. The angle θ between the direction x of the element co-ordinate system and the principal direction *pX* of the principal hot spot stress range co-ordinate system has to be determined.
- With 8-node shell element:
  With a $t_{n50} \times t_{n50}$ element mesh using 8-node element type, the element mid-side node is located on the line A-A at a distance *tn50* for type '*a*' hot spots. This node coincides with the stress read out point. The element surface stress components for load case '*i*1' and '*i*2' can be used directly without extrapolation within each adjacent element located on each side (side L, side R) of the line A-A as illustrated in Figure. 16. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor difference (between load case '*i*1' and '*i*2') calculated from each side of line A-A. The angle θ between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system has to be determined.

For fatigue assessment of type '*b*' hot spots, a beam element is to be used to obtain the fatigue stress range. The stress range is to be based on axial and bending stress in the beam element. The beam element is to have the same depth as the connecting plate thickness while the in-plane width is negligible.

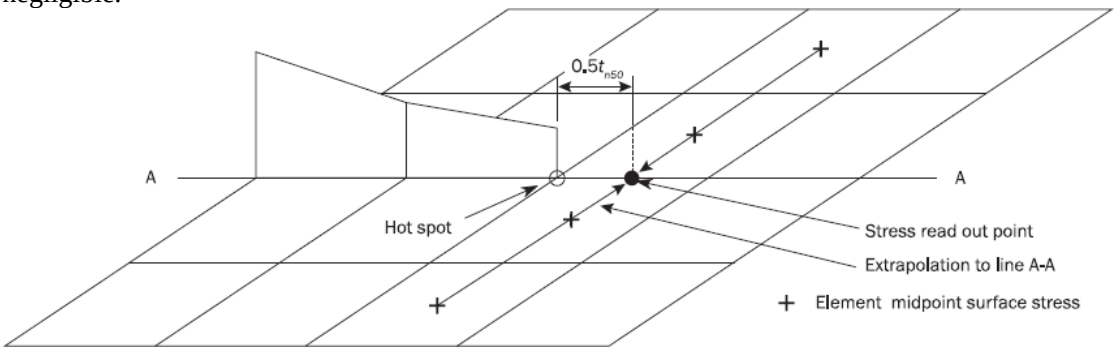


Figure 15 Determination of stress read out points and hot spot stress for 4-node element

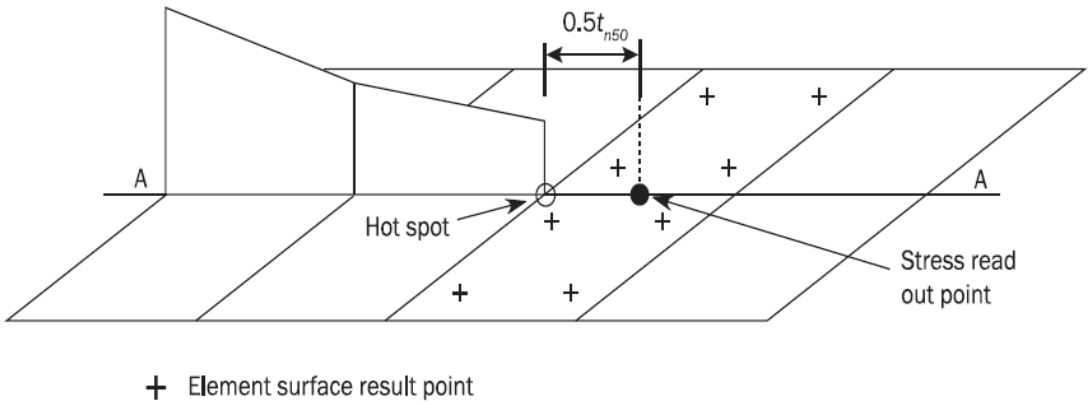


Figure 16 Determination of stress read out points and hot spot stress for 8-node element

3.1.3

The above read out procedure is based on element surface stresses. Generally, in FE software the element stresses are calculated at the Gaussian integration points located inside the element. Depending on the element type implemented in the FE software, it may be necessary to perform several interpolations in order to determine the actual stress at the considered stress read out point at the surface of the element mid-point or element edge.

3.2 Base material

3.2.1

For fatigue assessment at a free plate edge, a beam element is to be used to obtain the fatigue stress range. The beam element is to have the same depth as the connecting plate thickness while the in-plane width should be negligible.

3.3 Bent hopper knuckle

3.3.1

The hot spot stress at the inner bottom/hopper sloping plate and inner hull/hopper sloping plate in transverse, vertical and longitudinal directions (i.e. hot spots 1, 2 and 3 defined in Ch 9, Sec 2, Table 5 and Ch 9, Sec 2, Table 19) of a bent hopper knuckle is to be taken as the surface principal stress read out from a point shifted away from the intersection line between the considered member and abutting member by the weld leg length.

The hot spot stress, in N/mm^2, is obtained by the following formula:

$\sigma_{HS} = \sigma_{shift}$

where:

σ_{shift} : Surface principal stress, in N/mm^2, at the shifted read out position as defined in [4.2.1] and taken as:

$\sigma_{shift} = \sigma_{membrane}\,(x_{shift}) + \sigma_{bending}(x_{shift})$

$\sigma_{bending}\,(x_{shift})$: Bending stress, in N/mm^2, at x_{shift} position.

$\sigma_{membrane}(x_{shift})$: Membrane stress at x_{shift} position, in N/mm^2.

3.3.2

The procedure for calculation of hot spot stress at flange such as inner bottom /hopper sloping plate and inner hull/hopper sloping plate is the same that for web-stiffened cruciform joints as described in [4.2.1]. The procedure that applies for hot spots on the ballast tank side of the inner bottom/hopper plate and inner hull/hopper sloping plate in way of a bent hopper knuckle is in principle the same as that applied on the cargo tank side of the inner bottom plate for welded knuckle in Figure 18 and Figure 19. The intersection line is taken at the mid-thickness of the joint assuming median alignment. The plate angle correction factor and the reduction of bending stress as applied for a web-stiffened cruciform joint in [4.2.2] are not to be applied for the bent hopper knuckle type.

3.3.3

The stress at hot spots located in way of the web such as transverse web, side stringer and side girder (i.e. hot spots 4, 5 and 6 defined in Ch 9, Sec 2, Table 5 and Ch 9, Sec 2, Table 19) at a bent

hopper knuckle type is to be derived as described for web-stiffened cruciform joints in [4.3.1].

4 HOT SPOT STRESS FOR WEB-STIFFENED CRUCIFORM JOINT

4.1 Applicability

4.1.1

Among the structural details to be assessed listed in Ch 9, Sec 2, Table 3 the following structural details are considered as a web-stiffened cruciform joint:

4.1.1Welded hopper knuckle connection, shown in Figure 17.

4.1.2Heel of horizontal stringer, shown in Figure 17.

4.1.3Lower stool – inner bottom connection.

Two kinds of hot spots relative to the web-stiffened cruciform joints are to be assessed:

- Hot spots at the flange of web-stiffened cruciform joint,
- Hot spots in way of the web of web-stiffened cruciform joint.

4.1.2

The procedure for calculating hot spot stress at flange of web-stiffened cruciform joint is given in [4.2].

4.1.3

The procedure for calculating hot spot stress in way of the web of the web-stiffened cruciform joint is given in [4.3].

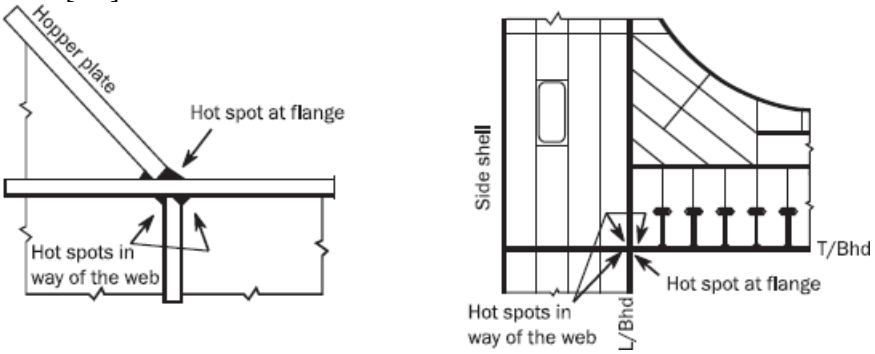


Figure 17 Web-stiffened cruciform joints

4.2 Calculation of hot spot stress at the flange

4.2.1

For hot spot at the flange of web-stiffened cruciform joints, the surface principal stress is to be read out from a point shifted away from the intersection line between the considered member and abutting member to the position of the actual weld toe and multiplied by 1.12. The intersection line is taken at the mid-thickness of the cruciform joint assuming a median alignment.

The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = 1.12\sigma_{shift}$

where:

σ_{shift}: Surface principal stress, in N/mm^2, at shifted stress read out position. The stress read out point shifted away from the intersection line is obtained as:

$$x_{shift} = \frac{t_{1-n50}}{2} + x_{wt}$$

where:

$t_{1\text{-}n50}$: Net plate thickness of the plate number 1, in mm, as shown in Figure 18.

x_{wt} : Extended fillet weld leg length, in mm, as defined in Figure 18, not taken larger than $t_{1\text{-}n50}$.

4.2.2

The stress at the shifted position is derived according to the following formula and illustrated in Figure 19:

$$\sigma_{shift} = \lceil \lfloor \sigma_{membrane}(x_{shift}) + 0.6 \cdot \sigma_{membrane}(x_{shift}) \rfloor \rfloor \cdot \beta$$

where:

$\sigma_{bending}(x_{shift})$: Bending stress, in N/mm^2, at the shifted position taken as:

$\sigma_{bending}\ (x_{shift}) = \sigma_{surface}\ (x_{shift}) - \sigma_{membrane}\ (x_{shift})$

$\sigma_{surface}\ (x_{shift})$: Total surface stress at x_{shift} position (including membrane stress and bending stress), in N/mm^2.

$\sigma_{membrane}\ (x_{shift})$: Membrane stress at x_{shift} position, in N/mm^2.

β : Plate angle hot spot stress correction factor, taken as:

- For α = 135°:

$$\beta = 0.96 - 0.13\frac{x_{wt}}{t_1} + 0.20(\frac{x_{wt}}{t_1})^2$$

- For α= 120°:

$$\beta = 0.97 - 0.14\frac{x_{wt}}{t_1} + 0.32(\frac{x_{wt}}{t_1})^2$$

- For α= 90°:

$$\beta = 0.96 + 0.031\frac{x_{wt}}{t_{1-n50}} + 0.24(\frac{x_{wt}}{t_{1-n50}})^2$$

α : Angle, in deg, between the plates forming a web-stiffened cruciform joint as shown in Figure 19.

Correction factors for connections with plate angles intermediate to those given should be derived based on a linear interpolation of the above values. The calculated hot spot stress is to be used in conjunction with the hot spot S-N curve for weld toe connections according to Ch 9, Sec 3, [4.2].

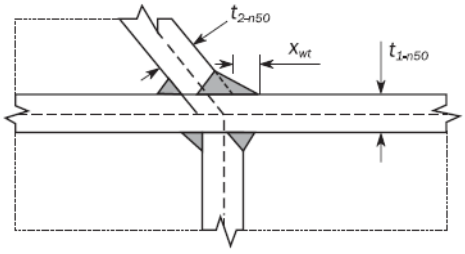


Figure 18 Geometrical parameters of web-stiffened cruciform connections

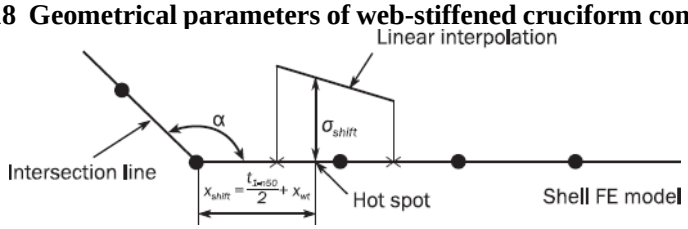


Figure 19 Procedure for calculation of hot spot stress at web-stiffened cruciform connections

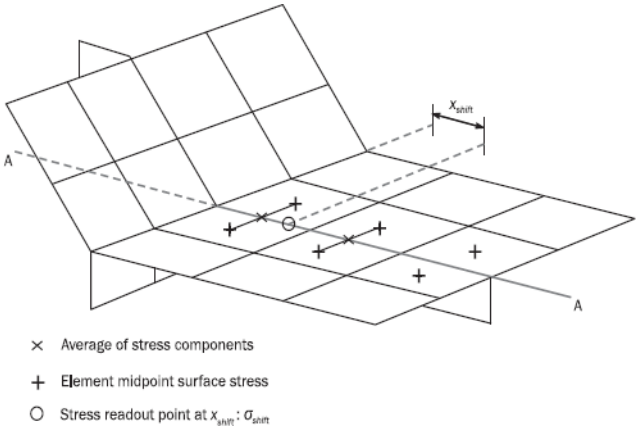


Figure 20 Determination of stress read out points for web-stiffened cruciform connections

4.2.3

Surface principal stresses at the centre point of the two first elements on left and right side of the line A-A are averaged and taken as the surface principal stresses in way of the web position (line A-A). The surface principal stresses for load case '*i1*' and '*i2*' are linearly interpolated along the

line A-A in order to determine hot spot principal stresses at the stress read out point located at the x_{shift} position as shown in Figure 20. The two principal hot spot stress ranges are determined at the stress read out point between load case '*i1*' and '*i2*'.

4.3 Calculation of hot spot stress in the web

4.3.1

Hot spots located in way of the web as indicated in Figure 21 are to be checked with the hot spot stress defined from the maximum principal surface stress at the intersection offset by the distance x_{shift} from the vertical and horizontal element intersection lines as illustrated in Figure 21. The intersection line is taken at the mid thickness of the cruciform joint assuming a median alignment. The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = \sigma_{shift}$

where:

σ_{shift} : Maximum principal surface stress, in N/mm^2, at the intersection offset by the distance x_{shift}.

The stress read out point at the intersection offset is obtained as:

$$x_{shift} = \frac{t_{3-n50}}{2} + x_{wt}$$

where:

$t_{3\text{-}n50}$: Net plate thickness of the web, in mm, as shown in Figure 21

x_{wt} : Extended fillet weld leg length, in mm, , taken as:

x_{wt} = min (l_{leg1},l_{leg2})

l_{leg1},l_{leg2} : Leg length, in mm, of the vertical and horizontal weld lines as shown in Figure 21.

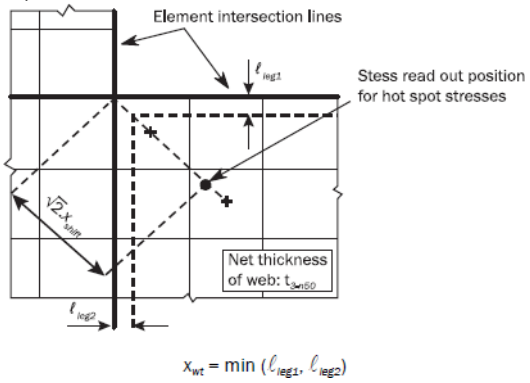


Figure 21 Hot spots in way of web

5 LIMITATIONS OF HOT SPOT STRESS APPROACH

5.1 Scope of application of hot spot stress approach

5.1.1

The hot spot stress approach given in Ch 9, Sec 1, [2.3.1] is not applicable for simple cruciform joints and simple T-joints when the stress flow in direction I as shown in Figure 22 is considered. For stresses in the direction normal to the weld at hot spot location "*c*" (direction I) there is no stress flow into the transverse plating as it is represented only by one plane in the shell model. However, it attracts stresses for in-plane direction (direction II) at hot spot location "*a*".

In situations where a bracket is fitted behind the transverse plate as shown in Figure 1, acting with stiffness in the direction normal to the transverse plate, stresses flow also into the transverse plate and the hot spot methodology is considered applicable.

5.1.2

The hot spot stress at position '*c*' for simple cruciform joints and simple T-joints is to be determined by the stress read out procedure given in [3.1] multiplied by a geometrical stress concentration factor of 1.3 and is taken as:

$\sigma_{HS} = 1.3 \cdot 1.12\sigma$

6 SCREENING FATIGUE ASSESSMENT

6.1 Screening procedure

6.1.1 Assumptions

The screening fatigue procedure is based on:

- Screening hot spot stress obtained by multiplying the stresses calculated from fine mesh analysis according to Ch 7, Sec 3 by the stress magnification factor of the considered structural detail.
- Mean stress effect and thickness effect are used according to Ch 9, Sec 3, [3.2] and Ch 9, Sec 3, [3.3].

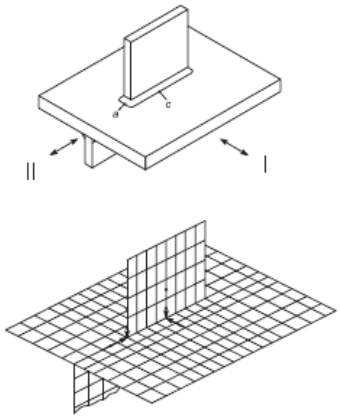


Figure 22 Illustration of check points in way of a welded attachment under orthogonal applied in plane loads

6.1.2 Procedure

The screening fatigue procedure includes the following three phases:

a) Phase 1: Calculation of fatigue stress.
   - Stresses are calculated at the stress read out point from the fine mesh element analysis with elements size of 50 ×50 mm, according to Ch 7, Sec 3 for all fatigue load cases defined in Ch 9, Sec 1, [7], for all loading conditions. Stresses to be used are element average membrane components stress defined in [6.2.3].
   - Hot- spot surface stress components are calculated for each load case '*i*1' and '*i*2' from the stresses multiplied by the stress magnification factor η, taken as:
     - $\sigma_{HS,\, i1(j)} = \eta \sigma_{S,\, i1(j)}$
     - $\sigma_{HS,\, i2(j)} = \eta \sigma_{S,\, i2(j)}$
   - Hot spot principal surface stress ranges are the difference of hot spot stress components obtained for each load case '*i1*' and '*i2*'.
   - Fatigue stress ranges for welded joints are determined from hot spot principal surface stress ranges with correction factor for mean stress and thickness effect.

   where:

   $\sigma_{S,\, i1(j)}$: Stress calculated from the fine mesh analysis in load case '*i1*' of loading condition (*j*) defined in [6.2].

   $\sigma_{S,\, i2(j)}$: Stress calculated from the fine mesh analysis in load case '*i*2' of loading condition (*j*) defined in [6.2].

   η : Stress magnification factor given in Table 2.

b) Phase 2: Selection of S-N curve.
   The S-N curve D defined in Ch 9, Sec 3, [4] is to be used with the fatigue stress range of weld toe in screening fatigue procedure.

c) Phase 3: Calculation of fatigue damage and fatigue life according to [6.1.3].

Stress magnification factor **Table 2**

Ship type	Structural detail category		Bulk hold	Stress magnification factor η
Oil tanker	Toe of stringer		-	2.45
	Bracket toe of transverse web frame		-	1.65
Bulk carrier	Lower hopper welded knuckle		FA(1)	2.28
			EA or C(1)	2.00
	Lower stool -Inner bottom	Non vertical (knuckle angle > 90°)	FA(1)	1.81
			EA or C(1)	1.47
		Vertical (knuckle angle = 90°)	FA(1)	2.09
			EA or C(1)	2.75
(1) FA and EA means "full cargo hold in alternate loading condition" and "empty cargo hold in alternate loading condition" respectively, C means cargo hold of BC-B and BC-C bulk carriers.				

6.1.3 Screening fatigue criteria

The total fatigue damage and the fatigue life of screened details are to comply with the criteria given in Ch 9, Sec 3, [2].

Structural details that do not comply with the acceptance criteria are to be checked with respect to fatigue strength using a very fine mesh finite element analysis as described in Ch 9, Sec 5.

6.2 Stress read out procedure

6.2.1 Bracket toe

For bracket toe, the stress read out point is located at a 50 mm distance away from the bracket toe as shown in Figure 23.

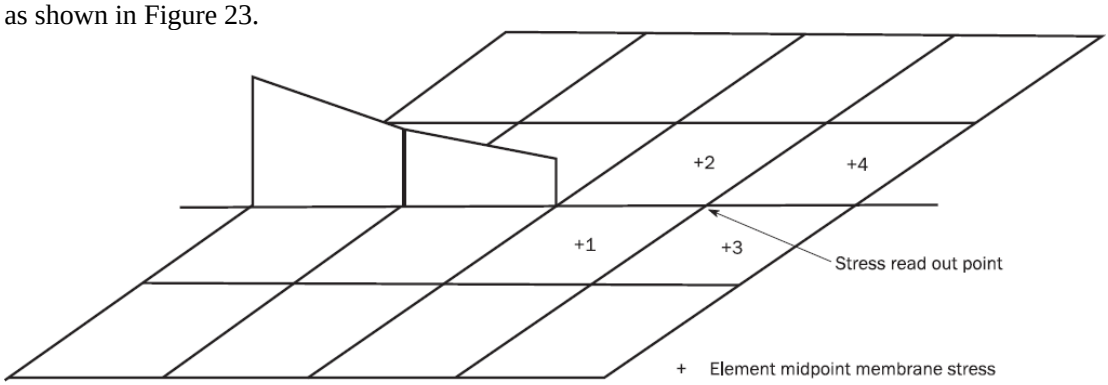


Figure 23 Stress read out point at bracket toe

6.2.2 Knuckle detail

For the lower hopper knuckle and for the connection between transverse bulkhead lower stool and inner bottom, the stress read out point is located at a 50 mm distance away from the knuckle line (i.e. model intersection line) as shown in Figure 24.

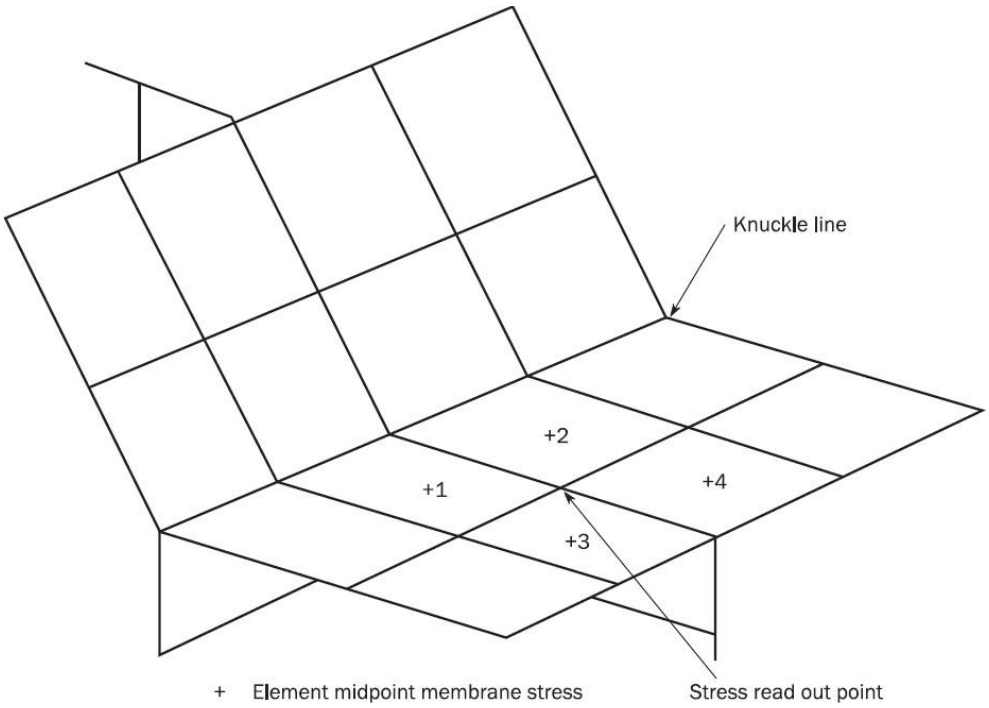


Figure 24 Stress read out point of knuckle detail

6.2.3 Read out point stress

The average of membrane stress components at the centre of four elements, modelled with elements size of 50 × 50 mm connected to the stress read out point (or node) can be used as read out point stress.

When the element size is less than 50 × 50 mm, the stress of read out point can be derived using elements in an equivalent area as shown in Figure 25.

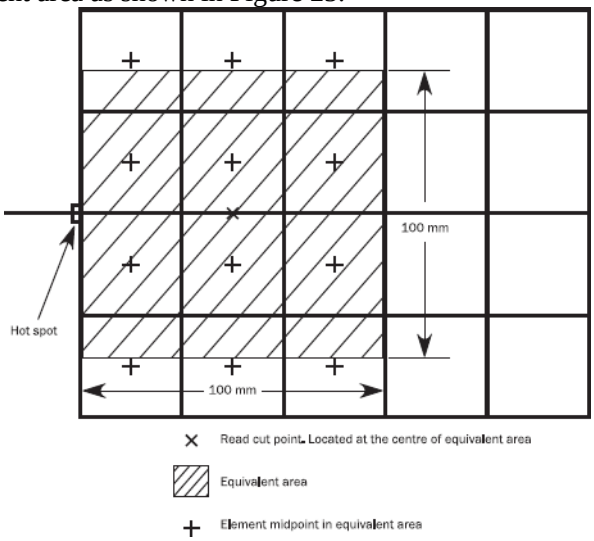


Figure 25 Equivalent area for element size less than 50 ×50 mm

Section 6 DETAIL DESIGN STANDARD

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Purpose

1.1.1
Design standard provides fatigue resistant detail design at an early stage in the structural design process by giving consideration to the following aspects:

- Application of fatigue design principles.
- Construction tolerances and other practical considerations.
- In-service experience and fatigue performance.

1.1.2
The design standard is to be applied to the design of ship structural details in following steps:

- Highlighting potential critical areas within the ship structure.
- Identification of the fatigue hot spot locations for each of the critical structural details.
- Provision of a set of alternative improved configurations from which a suitable solution can be selected.
- Requirements on geometrical configurations, scantlings, welding requirements and construction tolerances.
- Post fabrication method of improving fatigue life, such as weld toe grinding.

1.2 Application

1.2.1
The structural details described in this section are to be designed according to the given design standard but alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.
For the details given in Ch 9, Sec 2, Table 3, the fatigue assessment by very fine mesh finite element analysis may be omitted if the detail is designed in accordance with the design standard given in this section.

2 STIFFENER-FRAME CONNECTIONS

2.1 Design standard A

2.1.1
Designs for cut outs in cases where web stiffeners are omitted or not connected to the longitudinals are required to adopt tight collar or the improved design standard "*A*" as shown in Table 1 or equivalent, for the following members:

- Side shell below 1.1T_{sc}.
- Bottom.
- Inner hull longitudinal bulkhead below 1.1 T_{sc}.
- Topside tank sloping plating below 1.1 T_{sc}.
- Hopper.
- Inner bottom.

2.1.2
Designs that are different from those shown in Table 1 are acceptable subject to demonstration of satisfactory fatigue performance, e.g. by using comparative finite element analysis. The comparative FE analysis is to be performed following the modelling guidance given in Figure 1.

2.2 Equivalent design of stiffener-frame connections

2.2.1
If the required designs for stiffener-frame connections in [2.1] are not followed, the alternative design is to be verified to have equivalent fatigue strength to the design standard "A" or to be verified to have satisfactory fatigue performance. The alternative design is to be verified

according to the procedure given in [2.2.2] to [2.2.5] and documentation of results is to be submitted to the Society.

ISC 2.2.1a FE modeling

(1) FE model of standard design is to be established according to Table 1 of [2.1], and FE model of alternative design is also to be established according to the modeling method in [2.2.3].

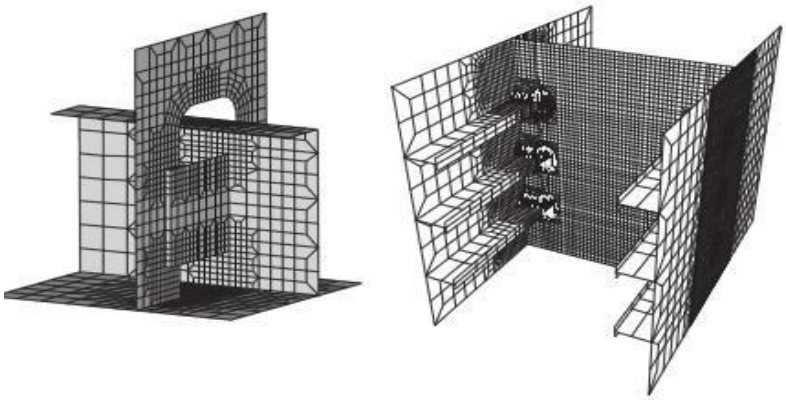


Figure 1 Finite element model for verification of equivalent design

(2) The mesh size in way of hot spot is in general to be t × t. When the hot spots are classified as hot spot type "b" as specified in 1.1.3 of Section 5 and Table 16 of Section 2, the mesh size is to be 10 ×10 mm. The mesh size is to extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in 2 of Section 5.

(3) Simulated beam elements are to be fitted in way of the edge of cut-out and hot spot type "b". The height of the simulated beam elements is to be consistent with plate thickness of web, the width may be neglected and the area is taken as 1 mm^2.

(4) Shell elements are to be used in the overlap scope of web of transverse frame and lug plates. In order to simulate fillet welds, web of transverse frame and lug plates are to be connected by shell elements in way of the boundary of overlap scope. The height of shell element is to be the distance between mid-layers of web of transverse frame and lug plates having a thickness equal to 2 times the net thickness of web plate, see Figure 2.2.1a(4).

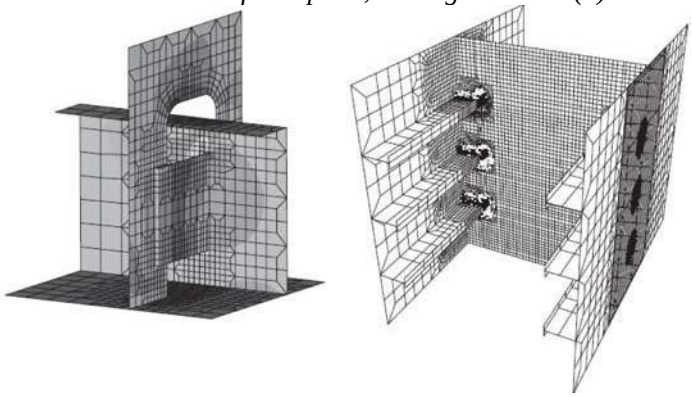


Figure 2.2.1a(1) FE Model of Equivalent Alternative Design

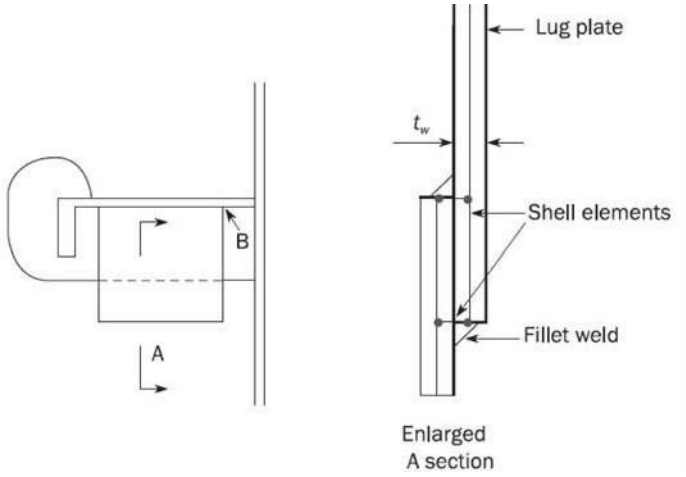


Figure 2.2.1a(4) Element Modeling of Overlap of Lug Plate and Web of Transverse Frame

ISC 2.2.1b Load case

(1) Three load cases are to be applied to the models of the standard design and alternative designs:

LC1: External pressure of unit value, fixed boundary conditions at top and bottom of model.

LC2: Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

LC3: Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

(2) The forward and aft part of the model are to have symmetry condition in a double hull structure. Load application and boundary conditions are shown in Figure ISC 2.2.1b(2).

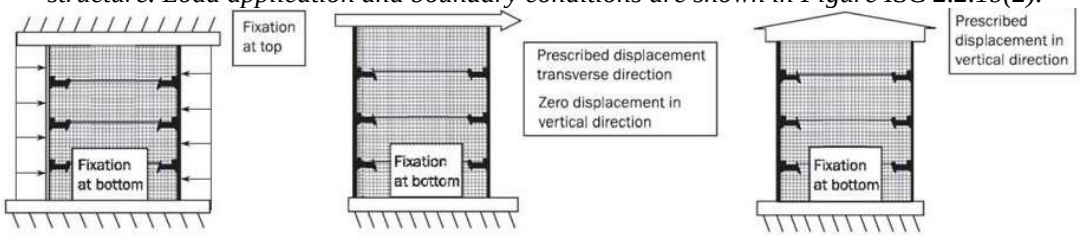


Figure ISC 2.2.1b(2) Load Application and Boundary Conditions

ISC 2.2.1c Reference stress

The stress for assessment is the maximum of the combination of axial and bending stress of simulated beam.

ISC 2.2.1d Assessment criteria of equivalent design

The reference stress (see ISC 2.2.1c) in way of critical hot spots around the cut-out of equivalent design is not greater than the corresponding value of standard design.

2.2.2

The procedure of [2.2.3] and [2.2.4] is provided to verify the alternative design to have equivalent fatigue strength with respect to any position in the transverse ring, i.e. double bottom and double side. The hot spot stress of the alternative design and that of the required design is to be compared to the critical hot spots in way of the cut-out. The critical hot spots depend on the detail design and are to be selected in agreement with the Society. The hot spot stress is to be derived according to Ch 9, Sec 5, [3.1] and Ch 9, Sec 5, [3.2]. It is to be noted that welded hot spots at the free edge are classified as hot spot type "*b*". Example of typical hot spots for checking is shown in Ch 9, Sec 2, [2].

ISC 2.2.2a The critical hot spots in way of the cut-out of alternative design for connection of stiffeners to transverse frames are selected as follows, see Figure ISC 2.2.2a:

(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure

ISC 2.2.2a;

(2) *intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure ISC2.2.2a;*

(3) *intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure ISC 2.2.2a;*

(4) *intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure ISC 2.2.2a (where hot spots 10 and 11 are located near the middle point of side length);*

(5) *intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure ISC 2.2.2a.*

ISC 2.2.2b In way of hot spots 10 and 11, the number of mesh along the side length is not to be less than4

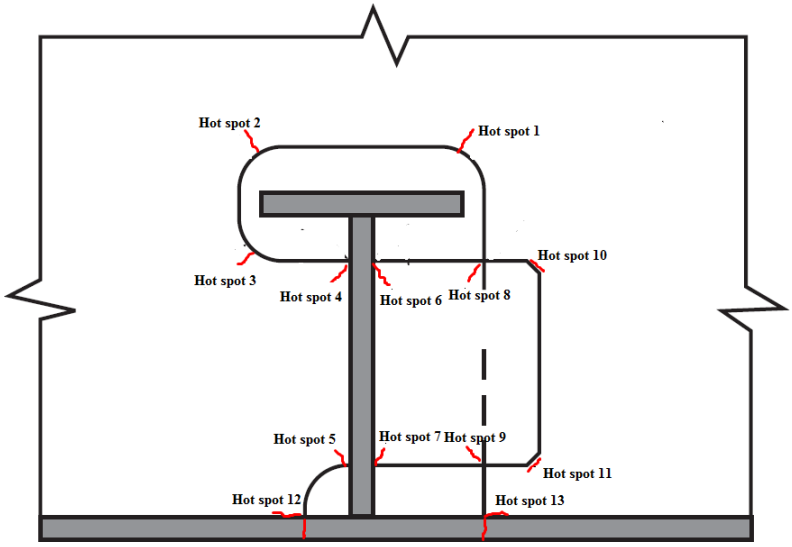
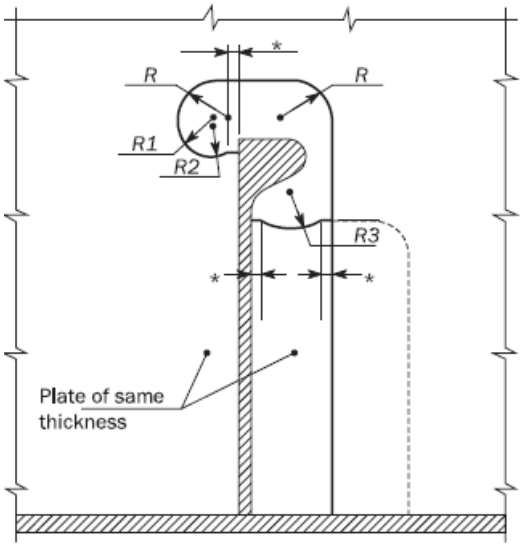
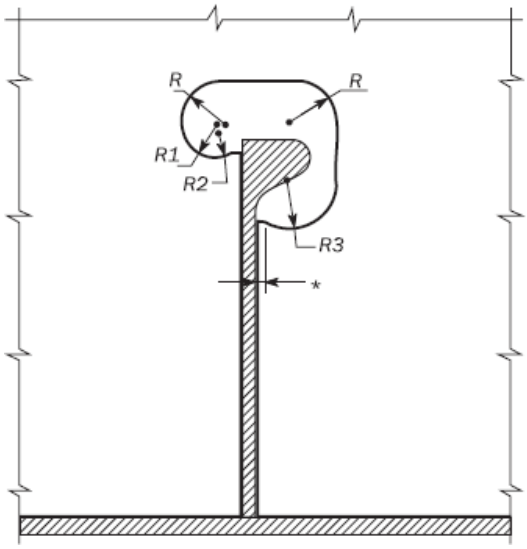
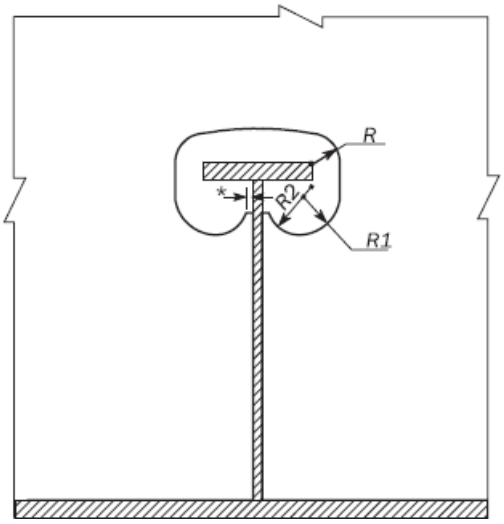
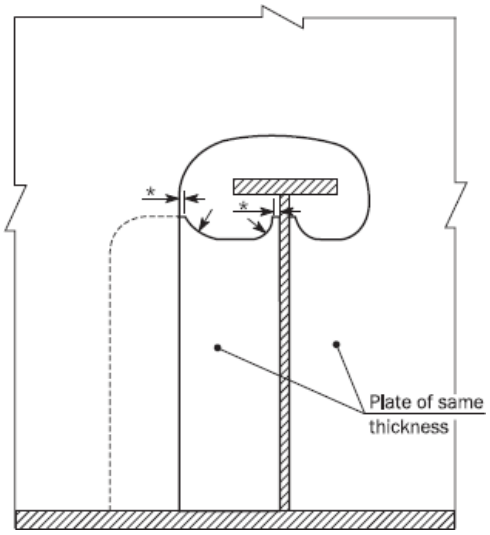


Figure ISC 2.2.2a Selection of Critical Hot Spot in way of Cut-out

Design standard A – stiffener-frame connection **Table 1**

Cut outs for longitudinals in transverse webs where web stiffeners are omitted or not connected to the longitudinal flange	
Design standard *A*	
1	2
	
3	4
	
Note1: Soft toes marked '*' are to be dimensioned to suit the weld leg length such that smooth transition from the weld to the curved part can be achieved. Maximum 15 mm or thickness of transverse web/collar plates/lug plates whichever is the greater. Note2: Configurations 1 and 4 indicate acceptable lapped lug plate connections.	

Critical location	Locations around cut-out with high stress concentration and locations in way of weld terminations
Detail design standard	Improved slot shape to avoid high stress concentrations in transverse webs due to shear loads and local pressure loads transmitted via welded joints
Building tolerances	Ensure alignment of all connecting members and accurate dimensional control of cut-outs according to IACS Recommendation No. 47.
Welding requirements	A wraparound weld, free of undercut or notches, around the transverse web connection to longitudinal stiffener web.

2.2.3

The very fine mesh finite element models are made to analyse the behaviour in way of double side or double bottom. The models should have an extent of 3 stiffeners in cross section, i.e. 4 stiffener spacings, and the longitudinal extent is to be one half frame spacing in both forward and aft direction. A typical model is shown in Figure 1. No cut-outs for access openings are to be included in the models. Connection between the lug or the web-frame to the longitudinal stiffener web, connections of the lug to the web-frame and free edges on lugs and cut-outs in web-frame are to be modelled with elements of net plate thickness size ($t_{n50} \times t_{n50}$). The mesh with net plate thickness size should extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in Ch 9, Sec 5, [2]. The eccentricity of the lapped lug plates is to be included in the model. Transverse web and lug plates are to be connected by eccentricity elements (transverse plate elements). The height of eccentricity element is to be the distance between mid-layers of transverse web and lug plates having a thickness equal to 2 times the net thickness of web-frame plate $t_{w\text{-}n50}$ Eccentricity elements representing fillet welds are shown in Figure 2.

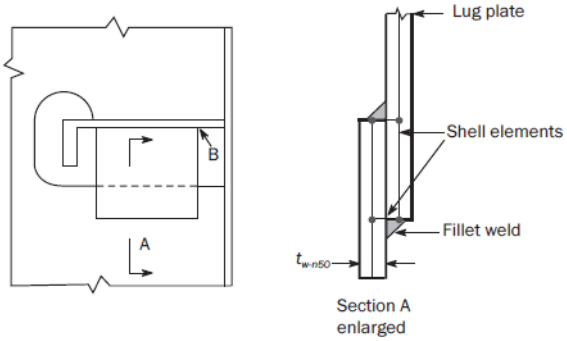


Figure 2 Modelling of eccentric lug plate by shell elements

2.2.4

Three load cases are to be applied to the models of the design standard and alternative designs:

- External pressure of unit value, fixed boundary conditions at top and bottom of model.
- Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.
- Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

The forward and aft part of the model should have symmetry condition describing the behaviour in a double hull structure. Load application and boundary conditions are provided in Figure 3.

2.2.5

The alternative design may also be verified to have satisfactory fatigue performance using sub-modelling technique where a very fine mesh model of the alternative design located at the actual position of the stiffener-frame connection is analysed. The alternative design is considered acceptable if the fatigue acceptance criterion of Ch 9, Sec 1 is achieved. The fatigue acceptance criterion is checked by applying the methodology described in Ch 9, Sec 1, Ch 9, Sec 3 and Ch 9, Sec 5. The alternative design is considered acceptable only for the particular position where it is analysed.

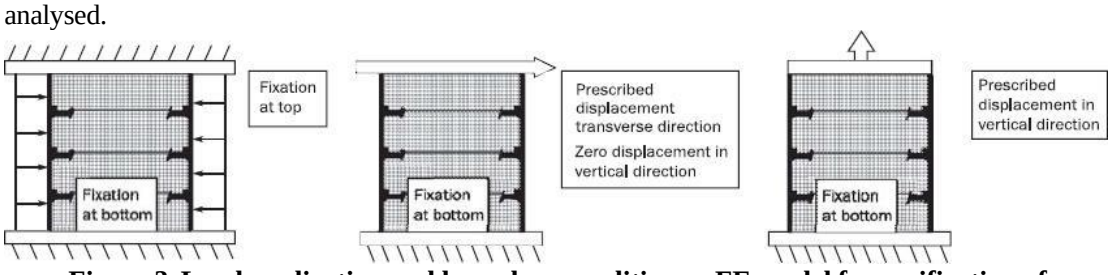


Figure 3 Load application and boundary conditions – FE model for verification of alternative design

3 SCALLOPS IN WAY OF BLOCK JOINTS

3.1 Design standard B

3.1.1
Scallops in way of block joints in the cargo tank/hold region, located on the stiffeners fitted on strength deck, and side above 0.9*D* from the baseline, are required to be designed according to the design standard B as shown in Table 2.

4 HOPPER KNUCKLE CONNECTION

4.1 Design standard C to H

4.1.1
The welded knuckle between hopper plating and inner bottom plating for double-hull oil tankers is to be designed according to the design standard C in Table 3. The design standard D in Table 4 may be used as an alternative to increase fatigue strength at the hopper connection.

4.1.2
The welded knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard E in Table 5.

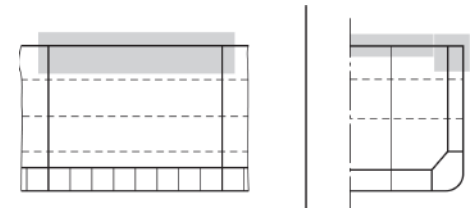
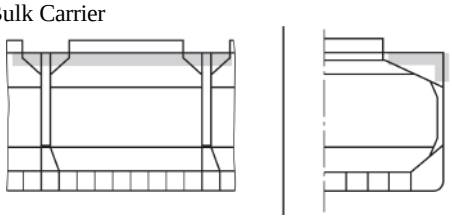
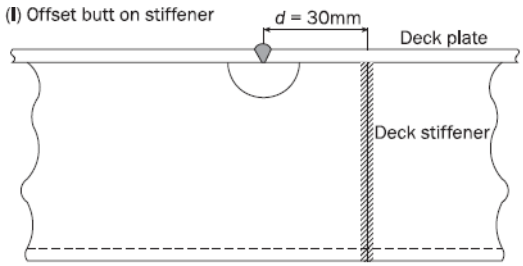
4.1.3
The radiused knuckle between hopper plating and inner bottom plating is to be designed according to the design standard F in Table 6 for double hull oil tankers.
Alternative structural arrangements may be accepted based on verification in accordance with Ch 9, Sec 5, [3.3].

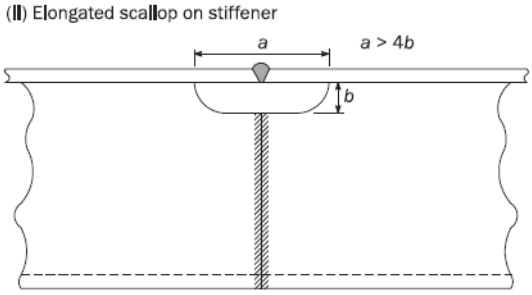
4.1.4
The radiused knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard G in Table 7.

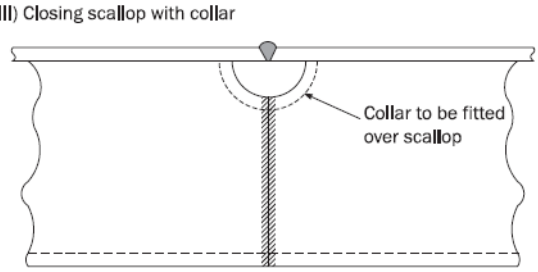
4.1.5
The radiused knuckle between hopper plating and inner side plating for oil tankers and double side bulk carriers is to be designed according to the design standard H in Table 8.

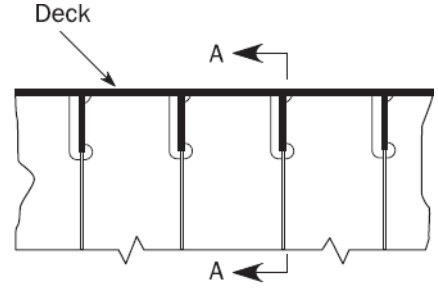
4.1.6
In general, the prescribed minimum requirements for welding, weld dressing and building tolerances as given in Table 3 to Table 8 are to be followed. Alternative positioning and/or dispensation of some support structure, such as transverse and longitudinal brackets may be accepted subject to demonstration of acceptable fatigue lives. Inserts and/or weld dressing additional to those prescribed may be required as a consequence of hot spot fatigue analysis.

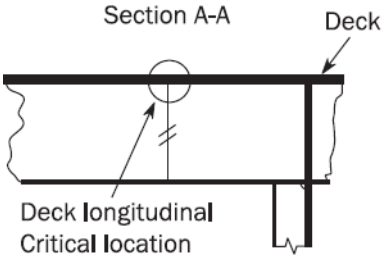
Design standard B – scallops in way of block joints **Table 2**

<table>
<tr><td colspan="2">Welding of deck stiffeners in way of block joints</td></tr>
<tr><td>Critical areas Design standard B</td><td>Critical areas Design standard B</td></tr>
<tr><td>Double-Hull Oil Tanker
 
Bulk Carrier
  </td><td rowspan="2"> 

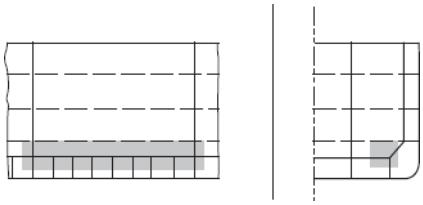
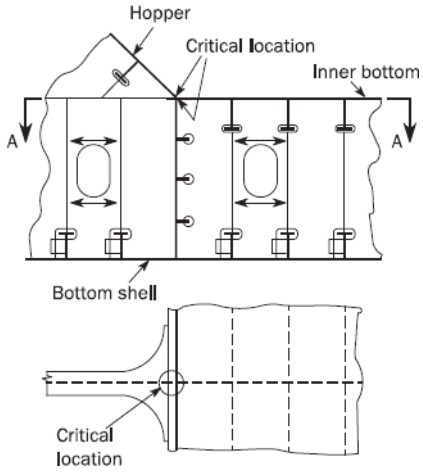
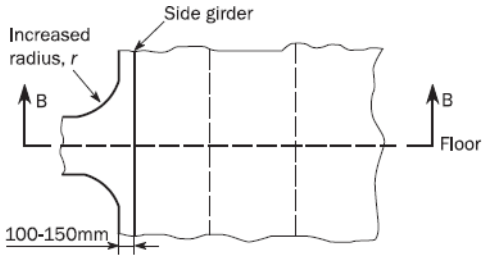
 

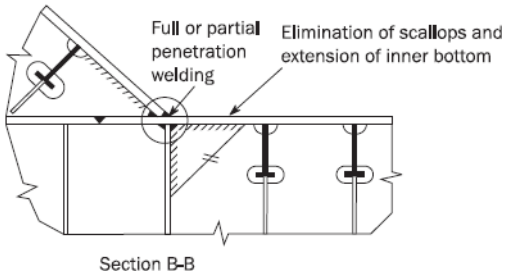
Note1: Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld</td></tr>
<tr><td>Critical locations
Transverse section
 

 
</td></tr>
</table>

Critical location	Welding of deck stiffeners in way of block joints in cargo tank region, the strength deck and side above 0.9*D* from the baseline.
Detail design standard	All scallops are to be fitted according to detail design standard B.
Building tolerances	Ensure alignment of all structural members according to IACS Recommendation No. 47.
Welding requirements	Full penetration butt weld, free of undercut or notches, around the web and flange of the longitudinal stiffener at block joints, particularly in way of the weld termination at the scallop for option II.

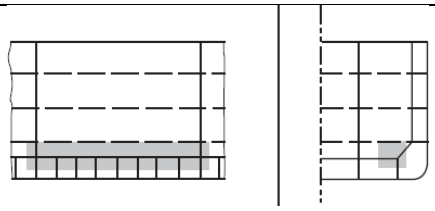
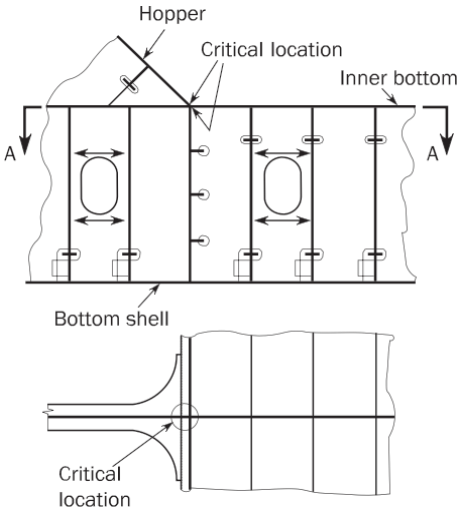
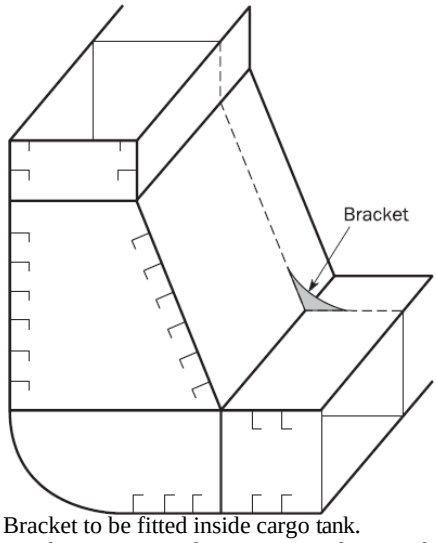
Design standard C – hopper knuckle connection detail, welded, without bracket, double hull oil tanker **Table 3**

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard C</td></tr>
<tr><td> 
Critical locations
 
</td><td> 

 
</td></tr>
</table>

Minimum requirement	As a minimum, detail design standard C or D is to be fitted. The ground surface is to be protected by a stripe coat of suitable paint composition, where the lower hopper knuckle region of cargo tanks is not coated.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness is to be close to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of the girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness. The allowable tolerance is to be measured parallel to the inner bottom.
Welding requirements	Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3 Weld between hopper plating and inner bottom plating to be enlarged and ground smooth. Visible undercuts are to be removed, see Ch 9, Sec 3, [6]. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor.

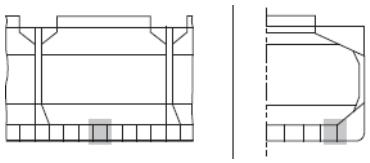
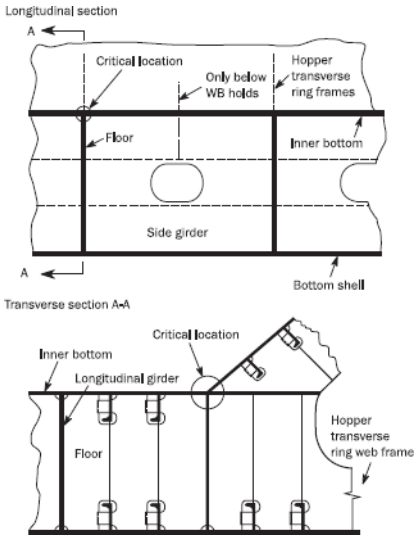
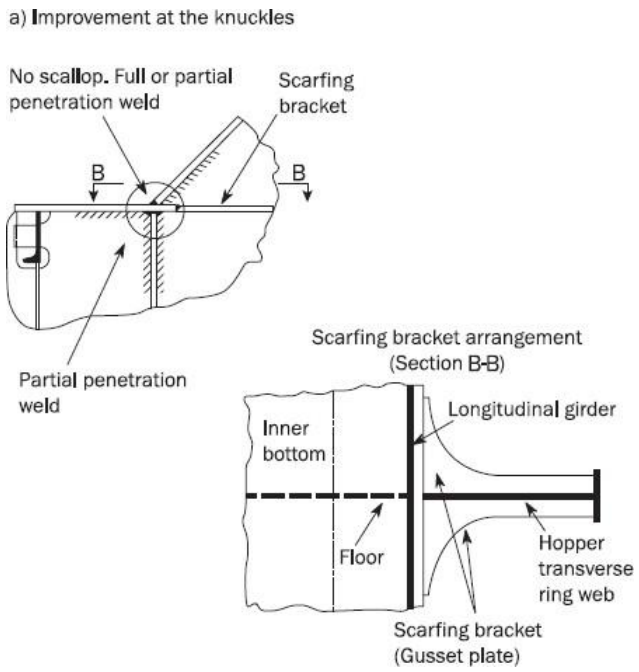
Design standard D – hopper knuckle connection detail, welded, with bracket, double hull oil Tanker Table 4

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard D</td></tr>
<tr><td> 
Critical locations
 
</td><td> 

Note1: Bracket to be fitted inside cargo tank.
Note2: Bracket to extend approximately to the first longitudinal.
Note3: The bracket toes are to have a soft nose design.
Note4: Bracket material to be same as that of inner bottom.
Note5: Slenderness of bracket to be in accordance with Ch 8, Sec 2, [5.2].</td></tr>
</table>

Minimum requirement	As a minimum, detail design standard C or D is to be applied.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners. The bracket connection to inner bottom and hopper sloping plate.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness similar to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.
Welding requirements	Partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection, to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Partial penetration welding is to be applied to the bracket connections to inner bottom and hopper sloping plate, full penetration welding is to be applied at bracket toes. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

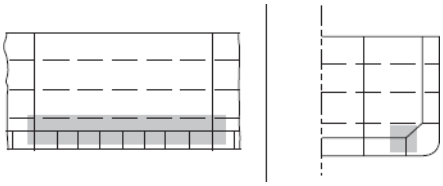
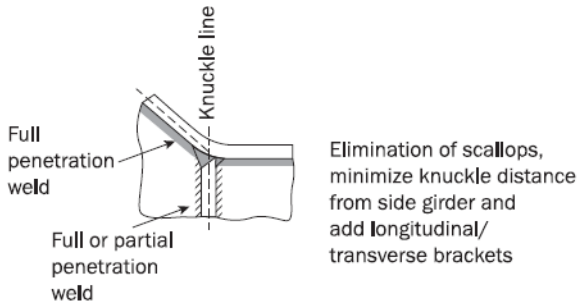
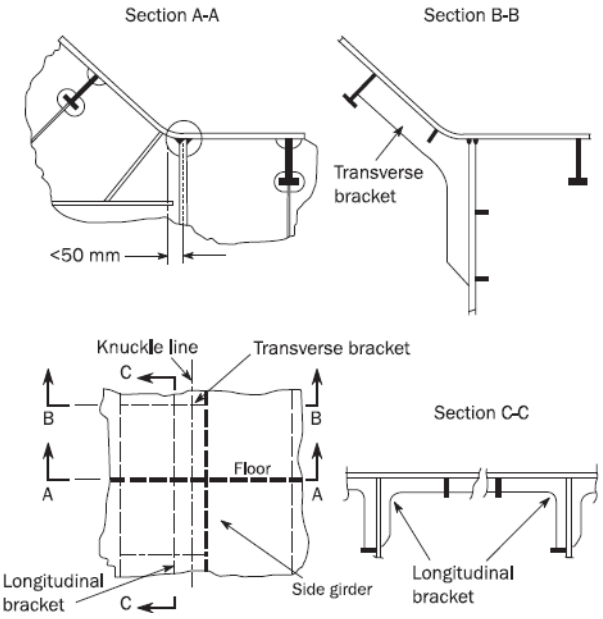
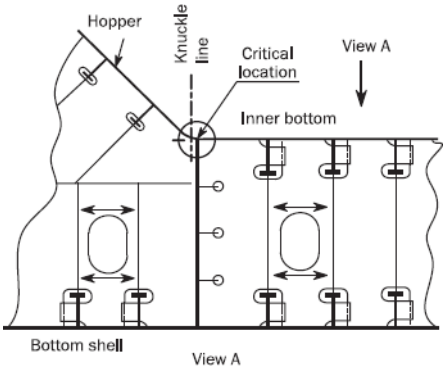
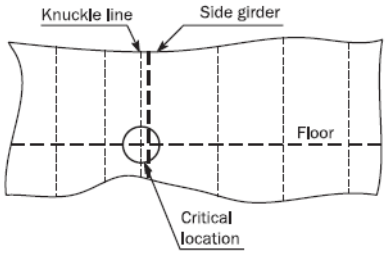
Design standard E – hopper knuckle connection detail, welded, bulk carrier Table5

Connections of floors in double bottom tanks to hopper tanks Welded knuckle connection of hopper tank sloping plating to inner bottom plating	
Critical areas	Design standard E
 Critical locations 	

Minimum requirement	As a minimum, detail design standard E is to be fitted. Ballast holds: No scallops or close scallops with collars; scarfing bracket; intermediate bracket if floor spacing greater than 2.5 m. Dry holds: No scallop or close scallops with collars and scarfing bracket.
Critical location	Hopper sloping plating connections to inner bottom plating in way of the floors. Floor connections to inner bottom plating and side girder in way of the hopper knuckle.
Detail design standard	Elimination of scallops in way of hopper knuckle, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket net thickness is to be minimum 80% of that of the inner bottom in way of knuckle and steel material to be of the same yield strength.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.
Welding requirements	Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection for the length of the cargo hold. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Weld between hopper plating and inner bottom plating is to be enlarged and ground smooth. Visible undercuts are to be removed. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

Design standard F – hopper knuckle connection detail, radiused type, for double hull oil tanker **Table 6**

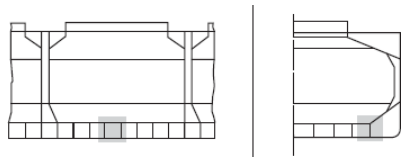
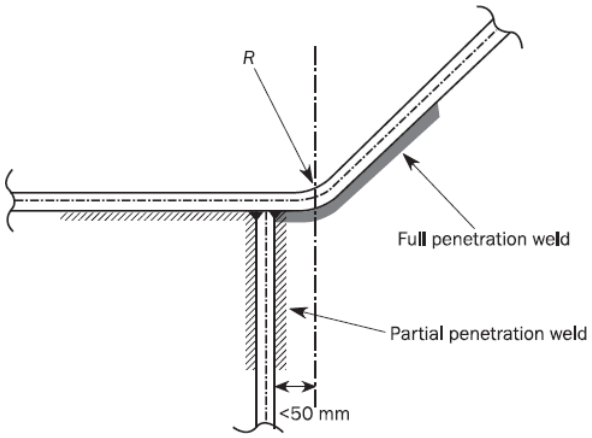
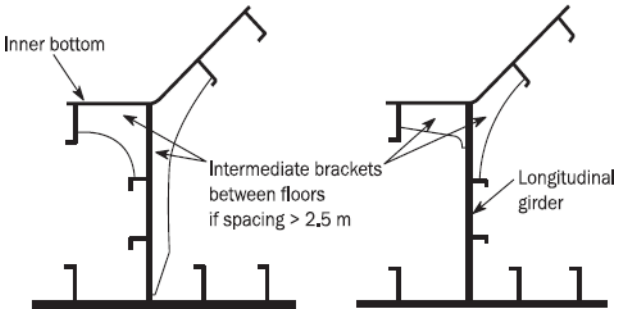
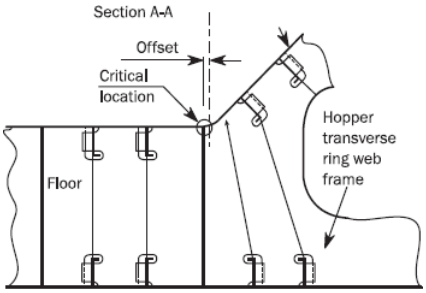
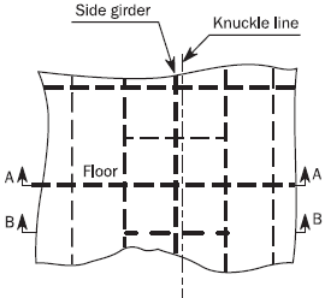
Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating

Critical areas	Design standard F
	
Critical locations	
 	Note1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm. Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part. Note3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection. Note4: Additional longitudinal bracket on the side of sloping plate. Note5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.

Critical location	Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively and to side girder in way of hopper knuckle. Side girder connections to inner bottom plating in way of floors.

Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Detail design standard	Elimination of scallops in way of hopper/girder connection and additional transverse and longitudinal brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure, and hull girder global loading, and provide additional support to sloping plate.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate) is not to exceed 1/3 of the as-built thickness of the side girder.
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper/inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to the side girder in way of hopper corner, and to connections of side girder to hopper/inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3. In order to improve the fatigue strength, weld enlargement and grinding are applicable to full and partial penetration welds with a minimum distance of 300 mm from the intersection point between the radiused knuckle, the floor and the side girder.

Design standard G – hopper knuckle connection detail, radiused type, bulk carrier Table 7

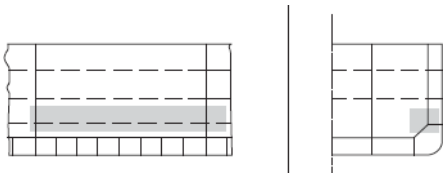
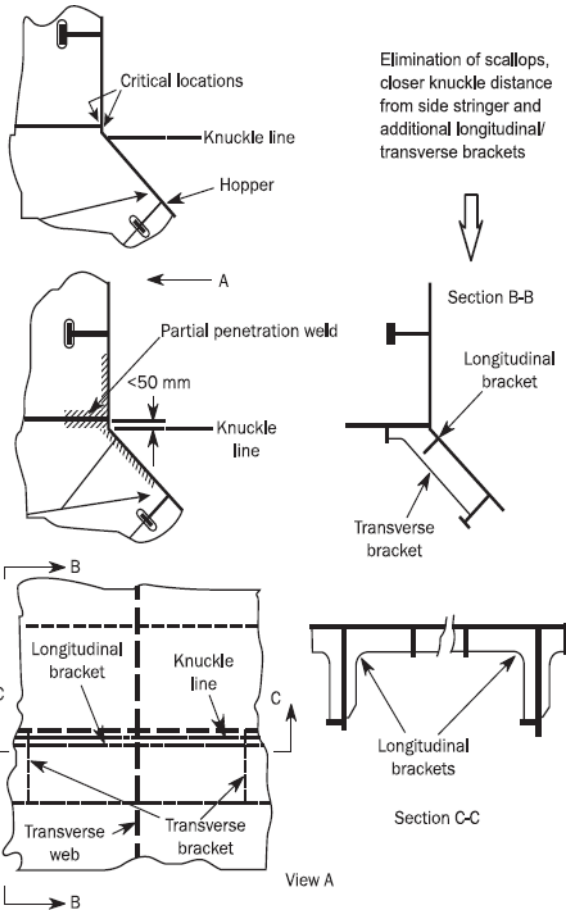
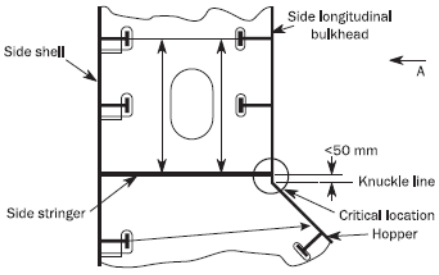
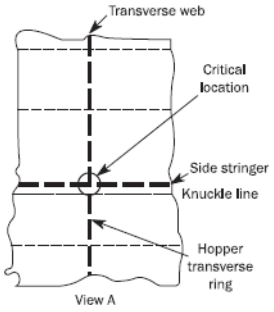
Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Critical areas	Design standard G
	 Intermediate bracket arrangement (Section B-B). Two intermediate brackets at both sides of floor/transverse web. 
Critical locations	
 	Note1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm. Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, in cases where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part. Note3: Additional transverse brackets on both side of transverse floor/hopper connection. Note4: Transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.

Critical location	Side girder connections to inner bottom plating in way of floors. Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively, and to side girder in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper/girder connection. Ballast holds: Intermediate brackets fitted at approximately 0.5 floor space from floor/hopper web. Dry holds: Intermediate brackets fitted at 0.5 floor space from floor/hopper web if floor spacing is equal to or greater than 2.5 m.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate and additional supporting brackets) should not exceed 1/3 of the as-built thickness of the side girder.

Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper /inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to side girder in way of hopper corners, to connections of side girder to hopper /inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

Design standard H – upper hopper knuckle connection detail, radiused type, oil tankers and double side bulk carrier **Table 8**

Connections of transverse webs in double side tanks to hopper tanks
Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating

Critical areas	Design standard H
	
Critical locations	
 	Note1: Distance from side stringer to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm. Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part, according to Ch 12 Sec 1 [3] & [4]. Note3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection. Note4: Additional longitudinal bracket on the side of sloping plate. Note5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch7, Sec 3 are fulfilled.

Critical location	Side stringer connections to side longitudinal bulkhead in way of transverse webs. Double side tank transverse web and hopper transverse web connections to side longitudinal bulkhead and to side stringers in way of hopper corners.

Connections of transverse webs in double side tanks to hopper tanks Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating	
Detail design standard	Elimination of scallops in way of hopper corners, closer knuckle distance from side stringers. Additional longitudinal / transverse brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure and cargo inertia pressure.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built thickness of the side stringer.
Welding requirements	Partial penetration welding is applied to connection of side stringers to side longitudinal bulkhead, connection of double side tank transverse webs to side longitudinal bulkhead and to side stringers, connection of hopper transverse webs to sloped side longitudinal bulkhead and to side stringers in way of hopper corners. Small scallops of suitable shape, which are to be closed by welding after completion of the continuous welding of side stringers to longitudinal bulkhead, are to be provided where scallops are eliminated. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

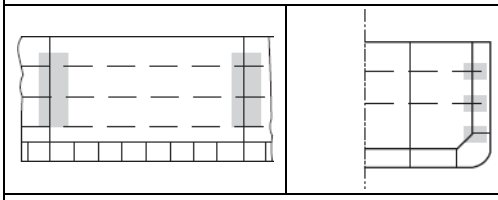
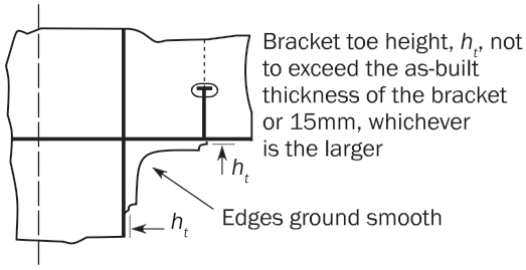
5 HORIZONTAL STRINGER HEEL

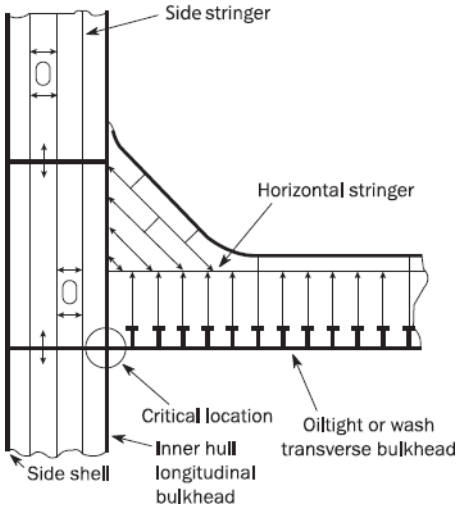
5.1 Design standard I

5.1.1

The horizontal stringer heel location between transverse oil-tight/swash bulkhead plating and inner hull longitudinal bulkhead plating for double hull oil tankers are required to be designed according to design standard I, as shown in Table 9.

Design Standard I – transverse bulkhead horizontal stringer heel **Table 9**

<table>
<tr><td colspan="3">Connections of horizontal stringer on plane oil-tight transverse bulkheads or wash bulkheads to inner hull longitudinal bulkheads</td></tr>
<tr><td colspan="2">Critical areas</td><td>Design standard I</td></tr>
<tr><td colspan="2">  </td><td rowspan="2"> 

Note1: Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g. taper and soft nose). Adequate fatigue life of the weld on the bracket edge in way of such terminations is to be confirmed.
Note2: ‘Slit type cut-outs are to be adopted in way of the bracket toe as shown. Alternatively, cut-outs with insert type collars will be accepted. Scallops are to be avoided.’</td></tr>
<tr><td colspan="2">Critical locations
 
</td></tr>
<tr><td>Critical location</td><td colspan="2">Intersections of webs of transverse bulkhead horizontal stringer and double side tank side stringer forming square corners.</td></tr>
<tr><td>Detail design standard</td><td colspan="2">A soft toe backing bracket is to be fitted. The following bracket sizes are recommended:
● VLCC: 800×800×30, R600 with soft toe as shown in figure above,
● Other tankers: 800×600×25, R550 with soft toe as shown in figure above, where the longer arm length is in way of the inner skin.
The specified minimum yield stress for the bracket is not to be less than 315 N/mm^2. The free edge is to be ground smooth with corners rounded.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built plate thickness of the inner hull longitudinal bulkhead.</td></tr>
<tr><td>Welding requirements</td><td colspan="2">Vertical weld between the inner hull plating and transverse bulkhead plating, fillet welding having minimum weld factor 0.44.
Welding between the backing bracket and the adjoining plates is to be double sided fillet welding having minimum weld factor 0.44 except in way of the bracket toes. Full penetration welding is to be used for the connection of bracket toes to the inner hull and transverse bulkhead plating for a distance of 200 mm from the toes and the weld toes are to be ground smooth in way.</td></tr>
</table>

6 BULKHEAD CONNECTION TO LOWER AND UPPER STOOL

6.1 Design standard J, K and L

6.1.1

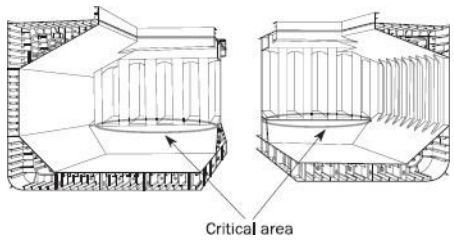
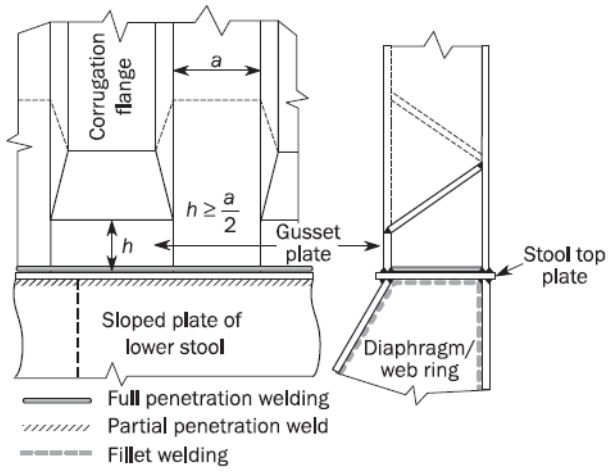
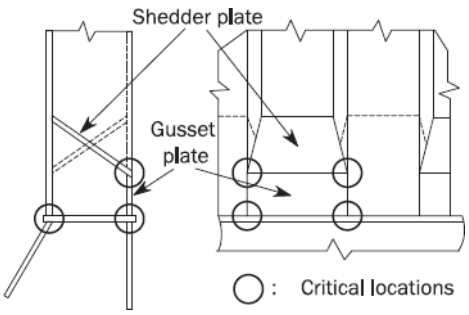
The welded connection of bulkhead to lower stool of bulk carriers and oil tankers are to be designed according to the design standard J and K respectively, as shown in Table 10 and Table 11.

6.1.2

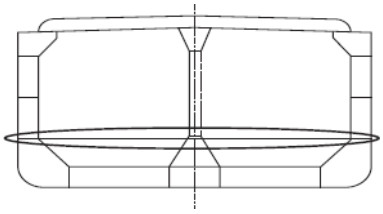
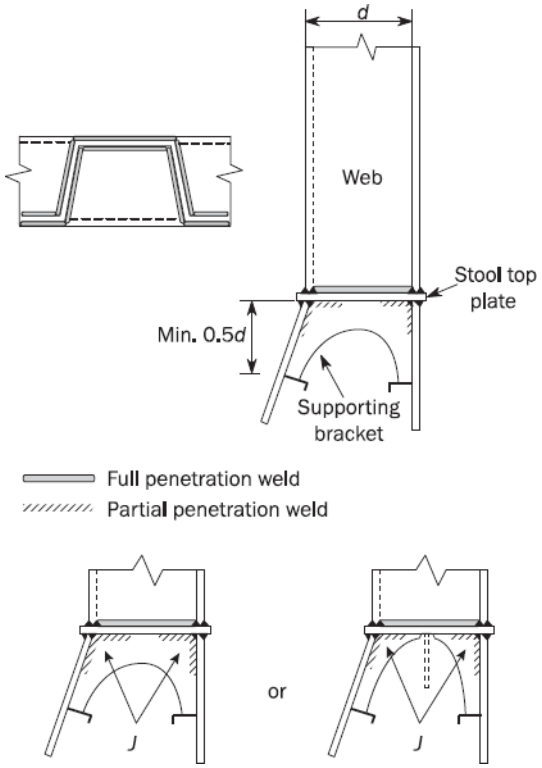
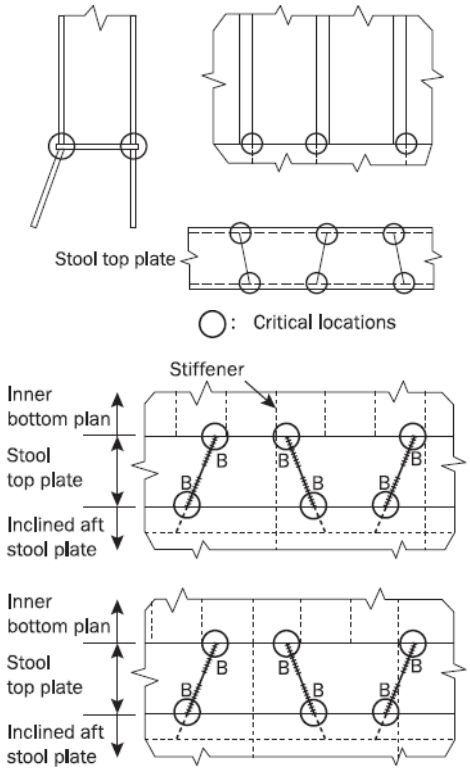
The welded connection of bulkhead to upper stool of bulk carriers are to be designed according to the design standard L, as shown in Table 12.

Design standard J – transverse bulkhead connection detail, bulk carrier (Ballast hold)

Table 10

<table>
<tr><td colspan="2">Connections of transverse bulkhead with lower stool</td></tr>
<tr><td>Critical areas</td><td>Design standard J</td></tr>
<tr><td> 
</td><td rowspan="2"> 
</td></tr>
<tr><td>Critical location
 
</td></tr>
<tr><td>Critical location</td><td>Connections of lower stool shelf plate to lower stool and corrugated transverse bulkheads.
Connections of shedder plates to corrugated transverse bulkhead.</td></tr>
<tr><td>Critical location</td><td>The use of scallops is to be avoided on diaphragms/web at lower stool top plates.
Gusset plates are to be fitted to corrugated bulkheads.
Gusset plates are to be made out of the same material and have the same as-built thickness as corrugated bulkheads; and, the height of gusset plates is to be greater than half of breadth of the corrugation.
To reduce stress concentrations at the crossing of the shedder plates one plate is to be moved higher than the other (as shown in Figure). Alternatively, bracketed stiffener can be fitted at the crossing points underneath the shedder plating facing the ballast hold.</td></tr>
<tr><td>Building tolerances</td><td>Ensure alignment between lower stool sloping plates and corrugation faces according to IACS Recommendation No. 47.</td></tr>
<tr><td>Welding requirement</td><td>Full penetration welding is to be applied between lower stool top plates and the side plating of lower stools and corrugated bulkheads.
Partial or full penetration welding is to be applied around gusset plates. However, full penetration welding is to be applied between lower stool top plates and gusset plates.
Ensure start and stop of welding is as far away as practicable from the critical corners.</td></tr>
</table>

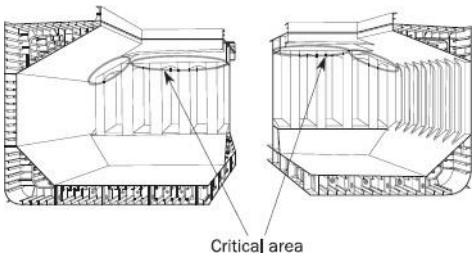
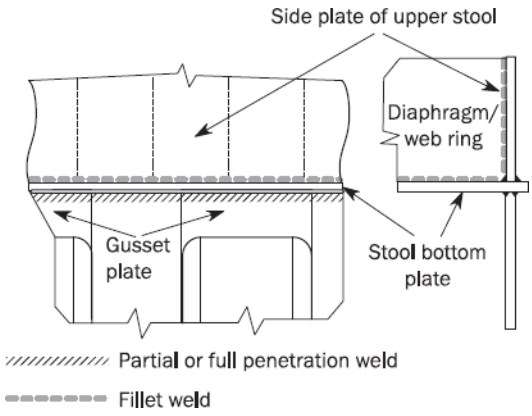
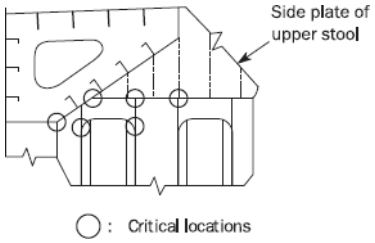
Design standard K – transverse or longitudinal corrugated bulkhead connection detail, oil tanker **Table 11**

<table>
<tr><td colspan="2">Connections of transverse or longitudinal bulkhead with lower stool - oil tanker</td></tr>
<tr><td>Critical areas</td><td>Design standard K</td></tr>
<tr><td>  </td><td rowspan="2"> 
</td></tr>
<tr><td>Critical locations
 
</td></tr>
</table>

Critical location	Connections of lower stool top plate to corrugated transverse or longitudinal bulkheads.
Detail design standard	The use of scallops is to be avoided on diaphragms/web at lower stool top plates. Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.
Building tolerances	Ensure alignment between lower stool side plates and corrugation faces according to IACS Recommendation No. 47.
Welding requirement	Full or partial penetration welding is to be applied between lower stool top plates and the side plating of lower stools. Full penetration welding is to be applied between lower stool top plates and vertical corrugated bulkheads. Full or partial penetration welding is to be applied between lower stool top plates and supporting brackets. Ensure start and stop of welding is as far away as practicable from the critical corners. Connection 'J', as shown in the figure, of in line supporting bracket to stool top plate and side plate of lower stool is to be full or partial penetration welding, on minimum 300 mm from the corner.

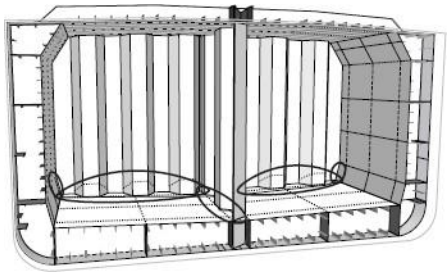
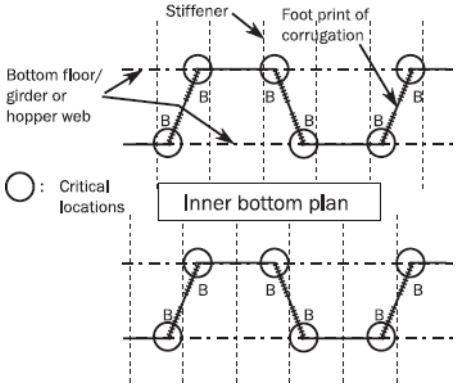
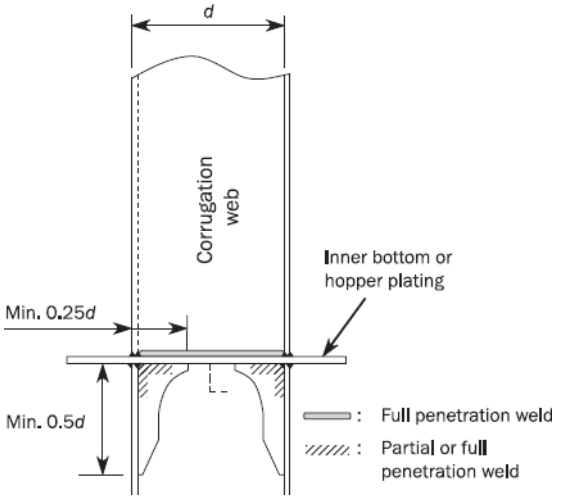
Design standard L – transverse bulkhead connection detail, bulk carrier (Ballast hold)

Table 12

<table>
<tr><td colspan="2">Connections of transverse bulkhead with sloped plate of upper stool</td></tr>
<tr><td>Critical areas</td><td>Design standard L</td></tr>
<tr><td> 
</td><td rowspan="3"> 
</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 
</td></tr>
</table>

Critical location	Connections of corrugated transverse bulkhead to the topside tank sloping plating and upper stool.
Detail design standard	The use of scallops is to be avoided on diaphragms/web at upper stool bottom plates. Gusset plates are to be fitted between the face plates of corrugated bulkheads in way of heavy ballast hold. In way of heavy ballast hold, a deep transverse web or well-stiffened backing stiffener is to be provided in the topside tank in line with the face plate of the bulkhead corrugations to ensure that the loads are effectively dissipated. Gusset plates are to have a thickness and material properties not less than those required for corrugation flanges.
Building tolerances	Ensure alignment between the face plates of corrugated bulkheads with the stool side plates as well as the watertight bulkheads and deep transverse web (or well- stiffened backing stiffener) in the topside tanks according to IACS Recommendation No. 47.
Welding requirement	Partial or full penetration welding is to be applied between upper stool bottom plates and corrugation. ● Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and upper stool side plating. ● Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and diaphragms/web rings. Ensure start and stop of welding is as far away as practicable from the critical corners in all holds.

Design standard M – connection details for vertically corrugated bulkheads in cargo tanks and heavy ballast hold **Table 13**

<table>
<tr><td colspan="2">Connections of vertically corrugated bulkhead to inner bottom/hopper plating without stool</td></tr>
<tr><td>Critical areas</td><td>Design standard M</td></tr>
<tr><td> 
Critical locations
 
</td><td>Detail of in line bracket:
 

Note1: Brackets are to be arranged below inner bottom and hopper tank plating in line with corrugation webs.
Note2: Where gusset plate with shedder plate according to Ch 6, Sec 4, [2.6.4] item b, is provided, in line bracket may be omitted on the side of gusset plate.</td></tr>
</table>

Critical location	-
Material and scantling requirement	Inner bottom and hopper tank plating in way of corrugations is to be in accordance to Ch 6, Sec 4, [2.6.4]. Floors/girders and hopper web that support corrugation flange is to be in accordance to Ch 6, Sec 4, [2.6.4]. Supporting bracket aligned with corrugation web is to be in accordance with Ch 8, Sec 2, [5.2] and Ch 6, Sec 4, [2.6.4].
Detail design standard	Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.
Building tolerances	Median line of corrugation is to be in line with the median line of the supporting members with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the inner bottom thickness.
Welding requirement	For the connection of vertically corrugated bulkheads to the inner bottom/hopper plating, full penetration welding is to be provided in according to Ch 12, Sec 3, [2.4]. For the connection of supporting structures to inner bottom/hopper plating, partial or full penetration welding is to be provided in accordance with Ch 12, Sec 3, [2.4]. Partial or full penetration welding is also to be applied for the connection of in line brackets below corrugation web in accordance with Ch 12, Sec 3, [2.4] on minimum 300 mm from the corner.

7 BULKHEAD CONNECTION TO INNER BOTTOM

7.1 Design standard M

7.1.1

The connection of vertically corrugated bulkhead to inner bottom/hopper plating of cargo tanks and heavy ballast hold are to be designed according to the design standard M, as shown in Table 13.

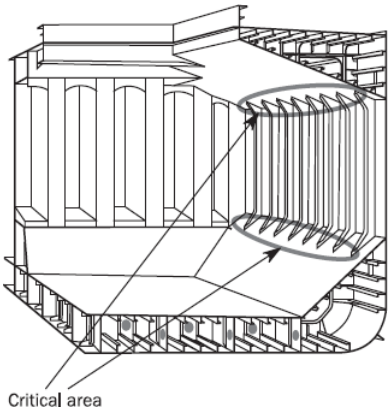
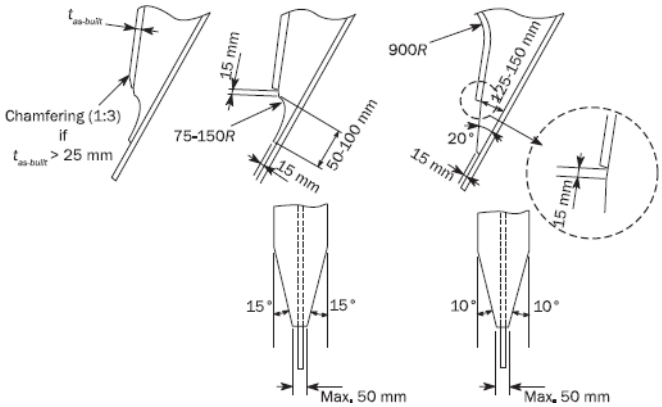
8 LOWER AND UPPER TOE OF HOLD FRAME

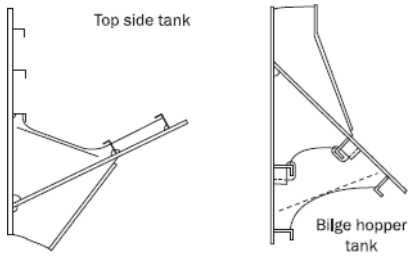
8.1 Design standard N

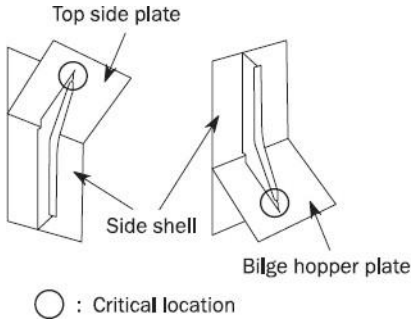
8.1.1

The welded connections of lower and upper bracket toes of hold frame of bulk carriers are to be designed according to design standard N, as shown in Table 14

Design standard N – lower and upper toe detail of hold frame - bulk carrier Table 14

<table>
<tr><td colspan="2">Lower and upper hold frame connections</td></tr>
<tr><td>Critical areas</td><td>Design standard N</td></tr>
<tr><td> 
</td><td rowspan="3"> 

Examples of the soft and extended toes at the end of hold frames.


Connection of lower and upper end bracket of hold frame.</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 
</td></tr>
<tr><td>Minimum requirement</td><td>As a minimum the detail design standard N is to be applied. Tapered extended toes are more effective and are to be considered for high tensile steel side shell frame.</td></tr>
<tr><td>Critical location</td><td>Toe connection of side shell frame lower and upper brackets to the hopper and topside sloping plates, including face plate terminations.</td></tr>
</table>

Lower and upper hold frame connections	
Detail design standard	Alternative geometries than stipulated above are permissible subject to demonstration of satisfactory fatigue performance. However, the maximum angles shown on the figures for thickness chamfering and face width tapering are not to be exceeded. Bracket toe height and the distance between the face plate termination and start of the toe radius (or toe taper) are to be kept to a minimum. The face plates of hold frames at lower or upper brackets are to be tapered and chamfered as shown. While chamfering may be dispensed with if the thickness of the face plates is less than 25 mm, it is nevertheless a recommended practice, with a larger gradient if necessary. Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft or elongated toes as shown. The side frame flange is to be curved (not knuckled) at the connection with the end brackets. Where the frame upper brackets are not positioned directly below a ring web, supporting brackets are to be provided. In the design ensure that if a topside tank stiffener is positioned above the end of frame upper bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area. Where the frame lower brackets are not positioned directly above a ring web, supporting brackets are to be provided. In the design ensure that if a hopper tank stiffener is positioned below the end of the frame lower bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area.
Building tolerances	Ensure alignment between side shell frame lower and upper bracket and transverse ring webs or supporting brackets according to IACS Recommendation No. 47. Maximum misalignment is to be not greater than $t_{as\text{-}built}$ /3 where $t_{as\text{-}built}$ is the thinner as-built thickness of the webs to be aligned and misalignment is the overhang of the as-built thinner thickness.
Welding requirement	Welding is to comply with Ch 12, Sec 3, [3]. In way of the wrap around weld at the face plate termination, care should be taken to ensure no over- run onto the radius part and the toe is free from notches and undercut.

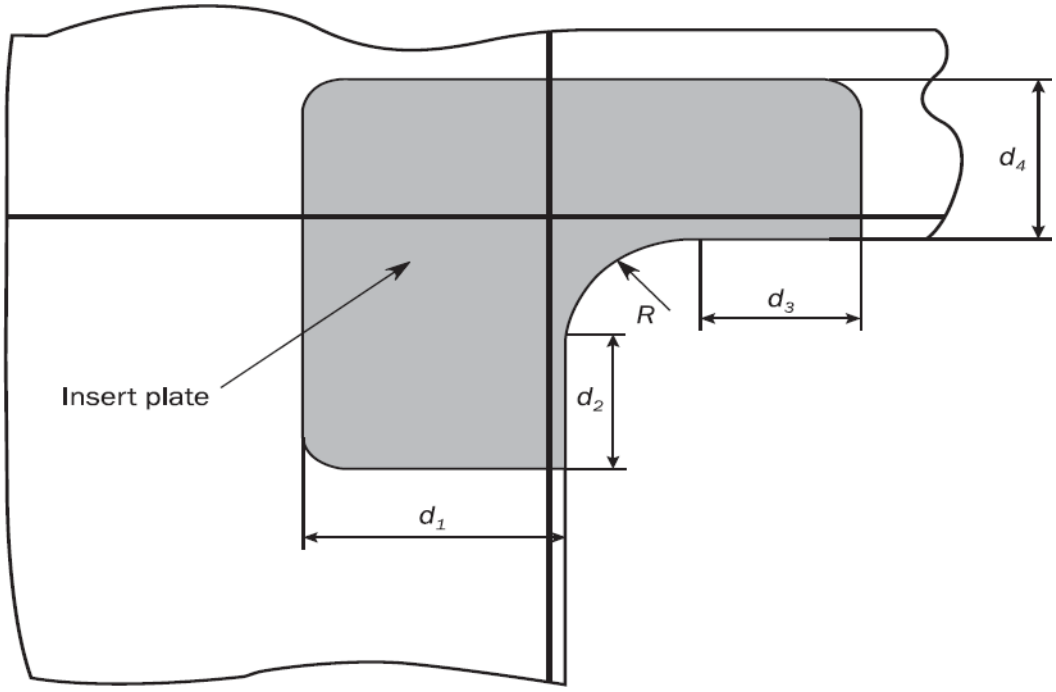
9 HATCH CORNER

9.1 Design standard O

9.1.1

Hatch corners in the cargo hold region, located on the strength deck of bulk carriers are required to be designed according to design standard O, as shown in Table 15.

Design standard O – hatch corner of bulk carriers **Table 15**

Hatch corner (bulk carriers)		
Design standard O		
		
	without insert plate	with insert plate
Critical location	Hatch corner curve	Curved Radius Transition insert plate to deck plating
Detail design standard	Shape of hatch corner as required by Pt 2, Ch 1, Sec 2	Radius and insert plate dimensions and thickness as required by Pt 2, Ch 1, Sec 2. Insert plate has to be tapered for smooth thickness transition to deck plating, the transition taper length has to be not less than 3 times the offset.
Post-treatment	Grinding of cut edge within the radius	Grinding of cut edge within the radius

Chapter 10 OTHER STRUCTURES

Section 1 FORE PART

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$ but not to be taken as greater than 1.0.

f_{bdg} : Bending moment factor taken as:

$$f_{bdg} = 8(1 + \frac{n_s}{2})$$

n_s : End fixation factor taken as:

n_s = 0 for both ends with low end fixity (simply supported).

n_s = 1 for one end fixed and one end simply supported.

n_s = 2 for continuous members or members with bracketed fitted at both ends

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the following structures of the fore part as defined in Ch 1, Sec 1, [2.4.2]:

- Fore peak structures.
- Stem.

In addition, the requirements of this section apply to structure subjected to impact loads:

- Flat bottom forward, according to [3.2].
- Bow area, according to [3.3].

2 STRUCTURAL ARRANGEMENT

2.1 Floors and bottom girders

2.1.1 Floors

In case of transverse framing, solid floors are to be fitted at each web frame location.

In case of longitudinal framing, the spacing of solid floors is not to be greater than 3.5 m or four transverse frame spaces, whichever is smaller.

The minimum depth of the floor at the centreline is not to be less than the required depth of the double bottom of the foremost cargo hold. See Ch 2, Sec 3, [2.3].

2.1.2 Bottom girders

A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the neighbouring cargo hold region, and the upper edge is to be stiffened.

In case of transverse framing, the spacing of bottom girders is not to exceed 2.5 m. In case of longitudinal framing, the spacing of bottom girders is not to exceed 3.5 m.

2.1.3 Alternative design verification

This spacing, defined in [2.1.1] and [2.1.2] may be increased, if the designer performs a verification of the bottom structure by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Wash bulkheads

2.2.1
Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.
Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

2.3 Side shell supporting structure

2.3.1 Web frames

The spacing of web frames, *S*, in m as defined in Ch 1, Sec 4, Table 5, is to be taken as:
$S = 2.6 + 0.005\,L$, but not to be taken greater than 3.5 m.
Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

2.3.2 Stringers

The transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures.

2.3.3 Alternative design verification

The spacing of web frames and stringers may be increased, if the designer performs a verification of the side shell supporting structure by means of beam analysis or FE analysis and provides their full documentation.
The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.4 Tripping brackets

2.4.1
For side shell and tank walls, located forward of the collision bulkhead and vertically framed, tripping brackets spaced not more than 2.6 m are to be fitted, according to Figure 1, between primary supporting members, decks and/or platforms.
The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

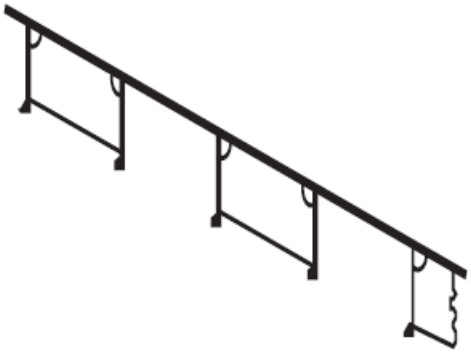


Figure 1 Tripping brackets

2.5 Bulbous bow

2.5.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.5.2 Diaphragm plates

At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1m apart in conjunction with a deep centreline web.
In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.5.3 Special bulbous bow designs

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is

generally to be fitted.
In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.5.4 Strengthening for anchor and chain cable contact

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [4.1.1].

3 STRUCTURE SUBJECTED TO IMPACT LOADS

3.1 General

3.1.1 Application

The requirements of this sub-section cover the strengthening requirements for local impact loads that may occur in the forward structure. The impact loads to be applied in [3.2] and [3.3] are described in Ch 4, Sec 5, [3].

3.1.2 General scantling requirements

The requirements of [3.2] and [3.3] are to be applied in addition to applicable scantling requirements in Ch 6. Local scantling increases due to impact loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

3.2 Bottom slamming

3.2.1 Application

Where the minimum draughts forward, $T_{F\text{-}e}$ or $T_{F\text{-}f}$, as specified in Ch 4, Sec 5, [3.2.1], are less than 0.045 L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures. The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, as required in Ch 1, Sec 5.
The load calculation point of the primary supporting members is specified in Ch 3, Sec 7, [4].

3.2.2 Extent of strengthening

The strengthening is to extend forward of 0.3 L from the FP over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see Figure 2.

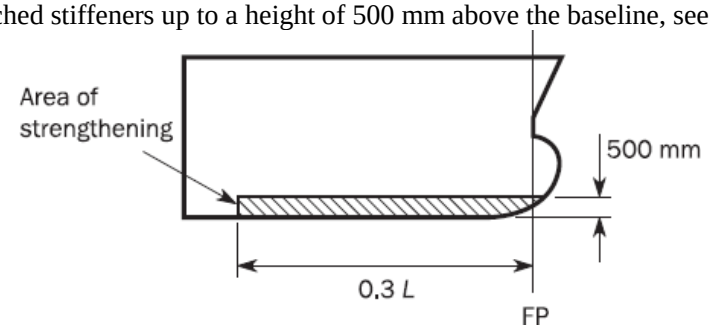


Figure 2 Extent of strengthening against bottom slamming

Outside the region strengthened to resist bottom slamming the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.2.3 Design to resist bottom slamming loads

The design of end connections of stiffeners in the bottom slamming region is to provide end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, *Zpl-alt*, in cm3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl}: Net plastic section modulus, in cm3, as required by [3.2.5].
Scantlings and arrangements of primary supporting members, including bulkheads in way of stiffeners, are to comply with [3.2.7].

3.2.4 Shell plating

The net thickness of the hull envelope plating, *t*, in mm, except for the transversely stiffened bilge plating within the cylindrical part of the ship, is not to be less than :

$$t = \frac{0.0158\alpha_p b}{C_d}\sqrt{\frac{P_{SL}}{C_a R_{eH}}}$$

where:

C_d :Plate capacity correction coefficient taken as:
C_d = 1.3.

C_a : Permissible bending stress coefficient taken as:
C_a = 1.0 for acceptance criteria set AC-I.

The transversely stiffened bilge plating within the cylindrical part of the ship is to comply with the requirement given in Pt 1, Ch 6, Sec 4, [2.2].

3.2.5 Shell stiffeners

The shell stiffeners within the strengthening area defined in [3.2.2] are to comply with the following criteria:

a) The net plastic section modulus, Z_{pl}, in cm^3, is not to be less than:

$$Z_{pl-alt} = \frac{P_{SL} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:
C_s : Permissible bending stress coefficient taken as:
C_s = 0.9 for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{SL} s l_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:
C_t : Permissible shear stress coefficient taken as:
C_t = 1.0 for acceptance criteria set AC-I.

c) he slenderness ratio is to comply with Ch 8, Sec 2.

3.2.6 Bottom slamming load area for primary supporting members

The scantlings of primary supporting members according to [3.2.7] are based on the application of the slamming pressure defined in Ch 4, Sec 5, [3.2] to an idealised slamming load area of hull envelope plating, A_{SL} , in m^2, given by:

$$A_{SL} = \frac{1.1 \cdot L \cdot B \cdot C_b}{1000}$$

3.2.7 Primary supporting members

The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in a):

a) Net shear area
The net shear area, $A_{shr\text{-}n50}$, in cm^2, of each primary supporting member web at any position along its span is not to be less than:

$$A_{shr-n50} \quad \frac{Q_{SL}}{C_t \tau_{eH}} = \frac{1}{0}$$

where:

Q_{SL} :The greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, *FSL* to the most onerous location, as determined in accordance with b) or c).

C_t : Permissible shear stress coefficient taken as:
C_t = 0.9 for acceptance criteria set AC-I.

b) Simplified calculation of slamming shear force
For simple arrangements of primary supporting members, where the grillage effect may be ignored, the shear force, Q_{SL}, in kN, is given by:
$Q_{SL}=f_{pt}f_{dist}F_{SL}$
where:
f_{pt} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as

$$f_{pt} = 0.5(f_{SL}^3 - 2f_{SL}^2 + 2)$$

f_{SL} : Patch load modification factor taken as:

$$f_{SL} = 0.5\frac{b_{SL}}{S}$$

f_{dist} : Factor for the greatest shear force distribution along the span, according to Figure 3.
F_{SL} : Patch load, in kN, taken as:
$F_{SL}=P_{SL}l_{SL}b_{SL}$
l_{SL} : Extent of slamming load area along the span, in m, taken as:

$l_{SL} = \sqrt{A_{SL}}$ but not to be greater than $0.5l_{shr}$.

b_{SL} : Breadth of impact area supported by primary supporting member, in m, taken as:

$b_{SL} = \sqrt{A_{SL}}$ but not to be greater than S.

A_{SL} : Surface defined in [3.2.6].

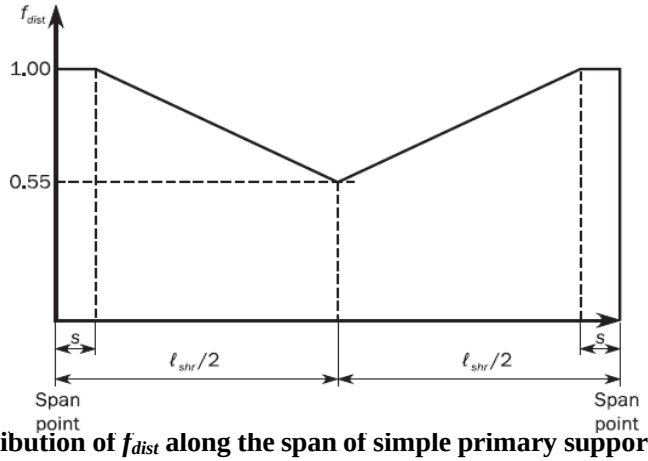


Figure 3 Distribution of f_{dist} along the span of simple primary supporting members

c) Direct calculation method for slamming shear force
For complex arrangements of primary supporting members, the greatest shear force, Q_{SL}, at any location along the span of each primary supporting member is to be derived by direct calculation in accordance with Table 1.

d) Web thickness of primary supporting member
The net web thickness, t_w, in mm, of primary supporting members adjacent to the shell is not to be less than:

$$t_w = \frac{s_W}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:
s_W : Plate breadth, in mm, taken as the spacing between the web stiffening.

3.3 Bow impact

3.3.1 Application

The side structure in the ship forward area is to be strengthened against bow impact pressures. The strengthening is to extend forward of 0.1 L from the FP and vertically above the minimum design

ballast draught, T_{BAL}, defined in Ch 1, Sec 4, [3.1.5] and forecastle deck if any. See Figure 4.

Direct calculation methods for derivation of Q_{SL} **Table 1**

Type of analysis	Model extent	Assumed end fixity of floors
Beam theory	Overall span of member between effective bending supports.	Fixed at ends
Double bottom grillage	Longitudinal extent to be one cargo tank length. Transverse extent to be between inner hopper knuckle and centreline.	Floors and girders to be fixed at boundaries of the model.
Note1: The envelope of greatest shear force along each primary supporting member is to be derived by applying the load patch on a square area as defined in [3.2.6], to a number of locations along the span. Note2: A more extensive model in length and breadth can be considered.		

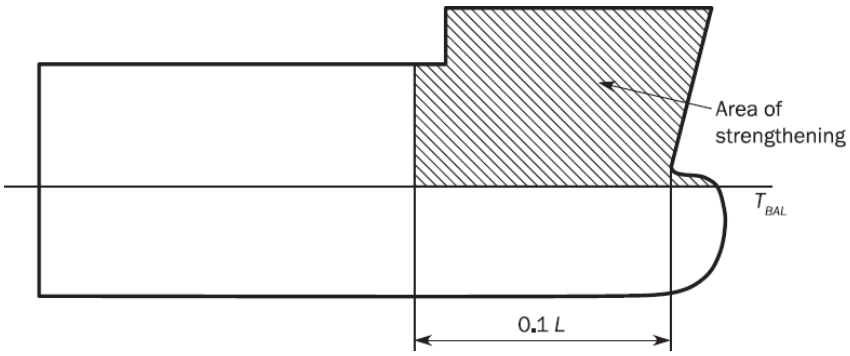


Figure 4 Extent of strengthening against bow impact

Outside the strengthening area the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.3.2 Design to resist bow impact loads

a) In1 the bow impact strengthening area, longitudinal framing is to be carried as far forward as practicable.

The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, Z_{pl-alt} in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Effective net plastic section modulus, in cm^3, required by [3.3.4].

b) Scantlings and arrangements of primary supporting members, including decks and bulkheads, in way of the stiffeners, are to comply with [3.3.6]. In areas of the greatest bow impact load, the web stiffeners arranged perpendicular to the hull envelope plating and the double sided lug connections are to be provided.

The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

3.3.3 Side shell plating

The net thickness of the side shell plating, t, in mm is not to be less than:

$$t = 0.0158 \alpha_p b \sqrt{\frac{P_{FB}}{C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient taken as:

C_a = 1.0 for acceptance criteria set AC-I.

3.3.4 Side shell stiffeners

The side shell stiffeners within the strengthening area defined in [3.3.1] are to comply with the following criteria:

a) The effective net plastic section modulus, Z_{pl}, in cm^3 in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl} = \frac{P_{FB} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

C_s : Permissible bending stress coefficient taken as:

C_s = 0.9 for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{FB} s l_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:

d_{shr}: Effective web depth of stiffener, in mm, as defined in Ch 3, Sec 7, [1.4.3].

C_t : Permissible shear stress coefficient taken as:

C_t = 1.0 for acceptance criteria set AC-I.

c) The slenderness ratio is to comply with Ch 8, Sec 2.

3.3.5 Bow impact load area for primary supporting members

The scantlings of primary supporting members according to [3.3.6] are based on the application of the bow impact pressure, as defined in Ch 4, Sec 5, [3.3.1], to an idealised bow impact load area of hull envelope plating, A_{BI}, in m^2, is given by:

$$A_{BI} = \frac{1.1 L B C_b}{1000}$$

3.3.6 Primary supporting members

a) The section modulus of the primary supporting member is to apply along the bending span clear of end brackets and cross sectional areas of the primary supporting member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in Figure 3.

b) Primary supporting members in the bow impact strengthening area are to be configured to provide effective continuity of strength and the avoidance of hard spots.

c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross section.

d) Tripping arrangements are to comply with Ch 8, Sec 2, [5.1.1]. In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary supporting member flange is knuckled or curved.

e) The net section modulus of each primary supporting member, Z_{n50}, in cm^3, is not to be less than:

$$Z_{n50} = 1000 \frac{f_{bdg-pt} P_{FB} b_{BI} f_{BI} l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg-pt} : Correction factor for the bending moment at the ends and considering the patch load taken as:

$$f_{bdg-pt} = 3f_{BI}^3 - 8f_{BI}^2 + 6f_{BI}$$

f_{BI} : Patch load modification factor taken as:

$$f_{BI} = \frac{l_{BI}}{l_{bdg}}$$

l_{BI} : Extent of bow impact load area, in m, along the span:

$l_{BI} = \sqrt{A_{BI}}$ but not to be taken as greater than l_{bdg}

b_{BI} : Breadth of impact load area, in m, supported by the primary supporting member, to be taken as the spacing between primary supporting members, S, as defined in Ch 1, Sec 4, Table 5, but not to be taken as greater than l_{BI}.

A_{BI} : Bow impact load area, in m^2, as defined in [3.3.5].

f_{bdg} : Bending moment factor taken as:

f_{bdg} = 12 for primary supporting members with end fixed continuous flange or where brackets at both ends are fitted in accordance with Ch3, Sec 6, [4.4].

C_s : Permissible bending stress coefficient taken as:

C_s = 0.8 for acceptance criteria set AC-I.

f) The net shear area of the web, $A_{shr-n50}$, in cm^2, of each primary supporting member at the support/toe of end brackets is not to be less than:

$$A_{shr-n50} = \frac{5 f_{PL} P_{FB} b_{BI} l_{shr}}{C_t \tau_{eH}}$$

where:

f_{PL} : Patch load modification factor taken as:

$$f_{PL} = \frac{l_{BI}}{l_{shr}}$$

l_{BI} : Extent of bow impact load area, in m, along the span taken as,

$l_{BI} = \sqrt{A_{BI}}$ but not greater than l_{shr}

C_t : Permissible shear stress coefficient taken as:

C_t = 0.75 for acceptance criteria set AC-I.

g) The net web thickness of each primary supporting member, t_w, in mm including decks/bulkheads directly welded to the side shell is not to be less than:

$$t_w = \frac{P_{FB} b_{BI}}{\sin\varphi_w \sigma_{cr}}$$

where:

φ_w : Angle, in deg, between the primary supporting member web and the shell plate, see Figure 5.

σ_{crb} : Critical buckling stress in compression of the web of the primary supporting member or deck/bulkhead panel in way of the applied load given by Ch 8, Sec 5, [2.2.3], in N/mm^2. In the calculation, both σ_x and σ_y given in Ch 8, Sec 5, [2.2.3] are to be considered and UP-B is to be applied.

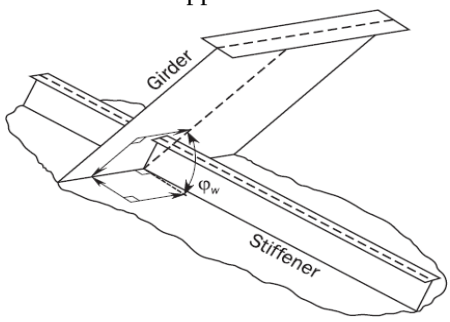


Figure 5 Angle between shell primary member and shell plate

4 ADDITIONAL SCANTLING REQUIREMENTS

4.1 Plate stem

4.1.1

The net thickness, t_{Stm} in mm, from keel line above to T_{SC} + 0.6 m is not to be less than:

$t_{Stm} = (0.6 + 0.4S_B)(0.08L + 2.7)\sqrt{k}$ but need not be greater than $22\sqrt{k} - 1$

where:

S_B: Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

Starting from 0.6 m above the summer load waterline up to T_{SC} + C_w, the net thickness may gradually be reduced to $0.8t_{Stm}$.

4.1.2 Breasthooks and diaphragm plating

The net thickness of breasthooks/diaphragm plates in way of bow impact strengthening area defined in [3.3.1], t_w in mm, is not to be less than:

$$t_w = \frac{s}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s : Spacing of stiffeners on the web, as defined in Ch 1, Sec 4, Table 5, in mm. Where no stiffeners are fitted, *s* is to be taken as the depth of the web.

4.2 Thruster tunnel

4.2.1

The net thickness of the tunnel plating, t_{tun}, in mm, is not to be less than the net required thickness for the shell plating in the vicinity of the bow thruster.

In addition, t_{tun} is not to be taken less than:

$t_{tun} = 0.008\, d_{tun} + 1.8$

where:

d_{tun} : Inside diameter of the tunnel, in mm, but not to be taken less than 970 mm.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

Section 2 MACHINERY SPACE

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the scantlings and arrangement of structures located in the machinery space. It is the shipyard responsibility to design the ship in accordance with the machinery manufacturer's requirements.

2 MACHINERY SPACE ARRANGEMENT

2.1 Structural arrangement

2.1.1

Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to support the deck, side, and bottom structure.

2.1.2

All parts of the machinery, shafting, etc, are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

2.1.3

Primary supporting members are to be positioned giving consideration to the provision of through stiffeners and in line pillar supports to achieve an efficient structural design.

2.1.4

The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces. Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

2.1.5

End connections of side longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-toe brackets. Brackets lapped onto the longitudinals are not to be fitted.

2.1.6

Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

2.1.7

Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

2.1.8

The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

a) Foundations for main propulsion units.
b) Foundations for reduction gears.
c) Foundations for thrust bearings.
d) Structure supporting a), b) and c).

2.2 Double bottom

2.2.1 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 2, Sec 3, [2.3.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be provided by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

2.2.2 Centreline girder

The double bottom is to be arranged with a centreline girder. In way of any openings for manholes on the centreline girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.2.3 Side bottom girders

In the machinery space, the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to provide adequate rigidity of the structure. The side bottom girders in longitudinal stiffened double bottom, are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.2.4 Girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seating.

2.2.5 Floors in longitudinally stiffened double bottom

Where the double bottom is longitudinally stiffened, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

2.2.6 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely stiffened, floors are to be arranged at every frame.

2.2.7 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2.8 Inner bottom plating

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

2.2.9 Heavy equipment

Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

3 MACHINERY FOUNDATIONS

3.1 General

3.1.1

Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

3.1.2

In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Type 1 of Figure 1.

3.1.3

For main machinery supported on foundations of Type 2, as shown in Figure 2, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Type 2 of Figure 2.

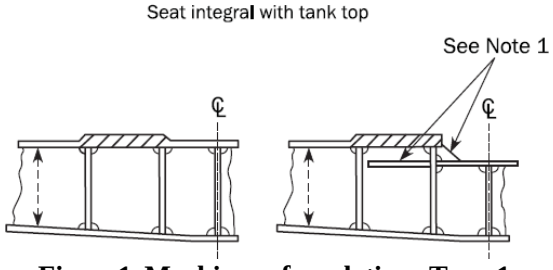


Figure1 Machinery foundations Type 1

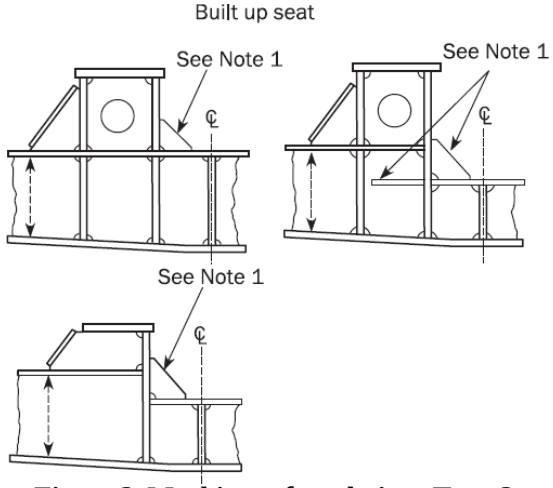


Figure 2 Machinery foundations Type 2

Note1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

3.2 Foundations for internal combustion engines and thrust bearings

3.2.1

In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

3.2.2

Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

3.3 Auxiliary foundations

3.3.1

Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

Section 3 AFT PART

SYMBOLES
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1
The requirements of this section apply for the scantlings and arrangement of structures located aft of the aft peak bulkhead.

2 AFT PEAK

2.1 Structural arrangement

2.1.1 Floors

Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.
Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

2.1.2 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.
Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.
Where the aft peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the aft peak are to be fitted with tapering brackets.
Where the depth from the peak tank top to the weather deck is greater than 2.6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

2.1.3 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.
Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

2.1.4 Alternative design verification

The spacing and arrangement requirements, defined in [2.1.1], [2.1.2] and [2.1.3] may be increased, if the designer performs a verification by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Stiffening of floors and girders in aft peak

2.2.1
Stiffeners on the floors and girders in aft peak ballast or fresh water tanks above propeller are to be designed in accordance with [2.2.2] and [2.2.3]. This applies for stiffeners located in an area extending longitudinally between the forward edge of the rudder and the after end of the propeller boss and transversely within the diameter of the propeller.

2.2.2
The height of stiffeners, h_{stf} , in mm, on the floors and girders are not to be less than:
$h_{stf} = 80 l_{stf}$ for flat bar stiffeners.

$H_{stf} = 70 l_{stf}$ for bulb profiles and flanged stiffeners.
where:
l_{stf} : Length of stiffener, in m, as shown in Figure 1. Length need not be taken greater than 5 m.

2.2.3
End brackets are to be provided as follows:

- Brackets are to be fitted at the lower and upper ends when l_{stf-t} exceeds 4 m.
- Brackets are to be fitted at the lower end when l_{stf-t} exceeds 2.5 m.

where:
l_{stf-t} :Total length of stiffener, in m, as shown in Figure 1.

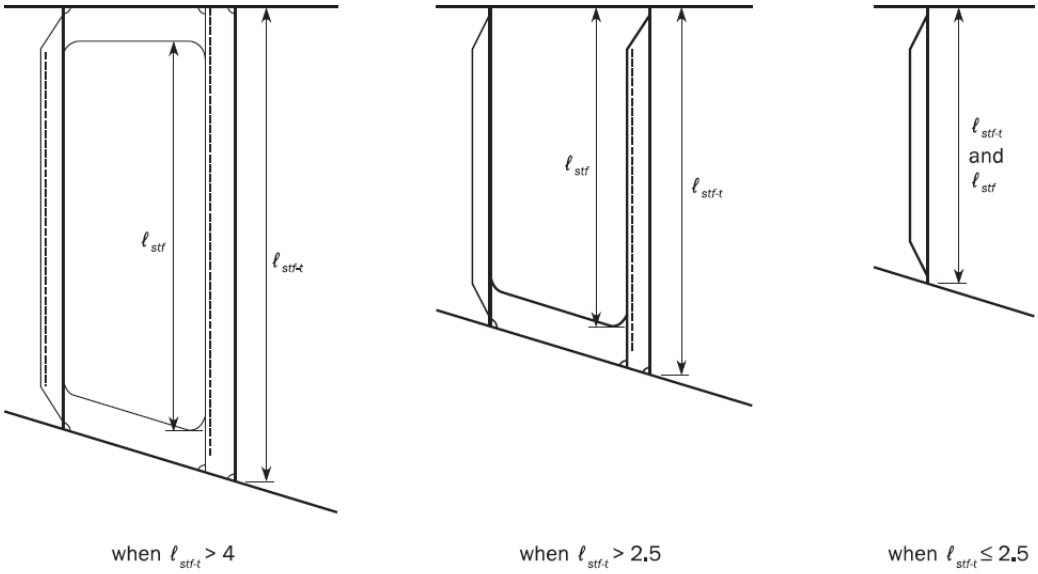


Figure 1 Stiffening of floors and girders in the aft peak tank

3 STERN FRAMES

3.1 General

3.1.1
Stern frames may be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch 3, Sec 1. Stern frames of other material or construction will be specially considered.

3.1.2
Cast steel and fabricated stern frames are to be strengthened by adequately spaced horizontal plates with gross thickness not less than 80% of required thickness for stern frames, t_1, as defined in Table 1 or Table 2. Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

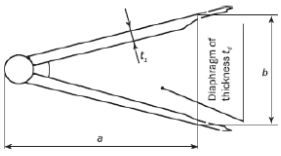
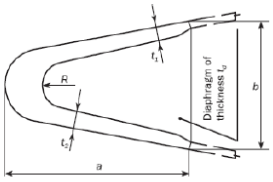
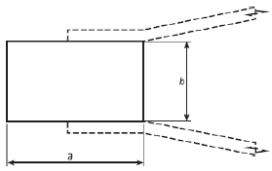
3.1.3
In the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement in [3.2.1].

3.2 Propeller posts

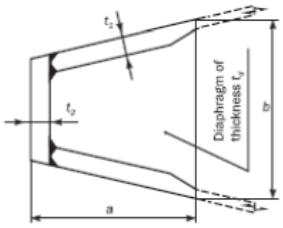
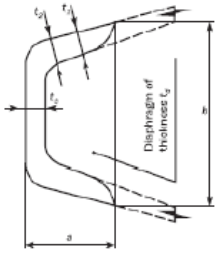
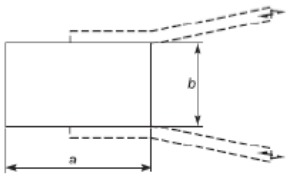
3.2.1 Gross scantlings of propeller posts

The gross scantlings of propeller posts are not to be less than those obtained from the formulae in Table 1 for single screw ships and Table 2 for twin screw ships.
Scantlings and proportions of the propeller post which differ from Table 1 and Table 2 may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Table 1 or Table 2, as applicable.

Single screw ships - Gross scantlings of propeller posts **Table 1**

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having rectangular section
			
a	$50\ L_1^{1/2}$	$33\ L_1^{1/2}$	$10\sqrt{7.2L-256}$
b	$35\ L_1^{1/2}$	$23\ L_1^{1/2}$	$10\sqrt{4.6L-164}$
t_1	$2.5\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_2	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-
R	-	50mm	-

Twin screw ships - Gross scantlings of propeller posts **Table 2**

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having rectangular section
			
a	$25\ L_1^{1/2}$	$12.5\ L_1^{1/2}$	$2.4L+6$
b	$25\ L_1^{1/2}$	$25\ L_1^{1/2}$	$0.8L+2$
t_1	$2.5\ L_1^{1/2}$	$2.5\ L_1^{1/2}$	-
t_2	$3.2\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_3	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-

3.2.2 Propeller shaft bossing

In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is not to be less than 60% of the dimension b required in [3.2.1] for bar propeller posts with a rectangular section.

3.3 Connections

3.3.1 Connections with hull structure

Stern frames are to be effectively attached to the aft structure and the required scantling for the lower part of the propeller post is to be extended from the aft end of the propeller post, at the centerline of the propeller shaft, to a length not less than $1500 + 6L_2$ mm, in order to provide an effective connection with the keel. However, the stern frame need not extend beyond the aft peak bulkhead.

3.3.2 Connection with keel plate

The thickness of the lower part of the stern frames is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the stern frame is to be designed to ensure an effective connection with the keel.

3.3.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having height not less than that of the double bottom height and a net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0.023\ L_1$

3.3.4 Connection with centre girder

Where the stern frame is made of cast steel, the lower part of the stern frame is to be fitted, as far as practicable, with a longitudinal web for connection with the centre girder.

4 SPECIAL SCANTLING REQUIREMENTS FOR SHELL STRUCTURE

4.1 Shell plating

4.1.1 Shell plating connected with stern frame

The net thickness of shell plating connected with the stern frame is not to be less than that obtained, in mm, from the following formula:

$t = 0.094\ (L_2 - 43) + 0.009\ b$

In way of the boss and heel plate, the net thickness, t, of shell plating, in mm, is not to be less than:

$t = 0.105\ (L_2 - 47) + 0.011\ b$

where:

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

4.1.2 Heavy shell plates

Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by [2.1.1]. The net thickness of heavy shell plates is not to be less than the value given in [4.1.1]. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, r in mm, is not to be less than:

$r = 150 + 0.8L_2$

4.1.3 Thruster tunnel plating

The net thickness of the tunnel plating, t_{tun} in mm, is to comply with the requirements in Ch 10, Sec 1, [4.2.1].

Section 4 TANKS SUBJECT TO SLOSHING

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$ but not to be taken as greater than 1.0.

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.1.1].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.1.1].

l_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.2], in m.

l_{slh} : Effective sloshing length, in m, as defined in Ch 4, Sec 6, [6.3.2].

b_{slh} : Effective sloshing breadth, in m, as defined in Ch 4, Sec 6, [6.4.2].

$I_{y\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in Ch 5, Sec 1, [1.5], in m4.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

z_n : Distance from the baseline to the horizontal neutral axis, as defined in Ch 5, Sec 1, in m.

z : Vertical coordinate of the load calculation point or at the reference point under consideration, in m.

σ_{hg} : Hull girder bending stress, in N/mm^2, calculated at the load calculation point defined in Ch 3, Sec 7, [2.2] or in Ch 3, Sec 7, [3.2], as the case may be:

$$\sigma_{hg} = (\frac{(z - z_n)M_{sw}}{I_{y-n50}})10^{-3}$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid.

Sloshing loads due to the free movement of liquid in tanks are given in Ch 4, Sec 6, [6].

1.2 General requirements

1.2.1 Filling heights of cargo and ballast tanks

The scantlings of all cargo and ballast tanks are to comply with the sloshing requirements given in this section for the following cases:

- Unrestricted filling height for ballast tanks,
- Unrestricted filling height for cargo tanks with cargo density equal to ρ_L, as defined in Ch 4, Sec 6,
- All filling levels up to h_{part} for cargo tanks with cargo density equal to ρ_{part} taken as:

$$h_{part} = \frac{h_{tk} \cdot \rho_L \cdot f_{cd}}{\rho_{part}}$$

where:

h_{part} : Maximum permissible filling height, in m, associated with a partial filling of the considered cargo tank with a high liquid density equal to ρ_{part}

h_{tk} : Maximum tank height, in m.

ρ_L : Cargo density as defined in Ch 4, Sec 6.

f_{cd} : Factor defined in Ch 4, Sec 6.

ρ_{part} : Maximum permissible high liquid density as defined in Ch 4, Sec 6.

1.2.2 Cargo holds of bulk carrier intended for the carriage of ballast water

Cargo holds of bulk carrier intended for the carriage of ballast water are assumed either full or empty in seagoing condition and are not required to be assessed for sloshing pressures.

1.2.3 Structural details

Local scantling increases due to sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

1.3 Application of sloshing pressure

1.3.1 General

The structural members of the following tanks are to be assessed for the design sloshing pressures $P_{slh\text{-}lng}$ and $P_{slh\text{-}t}$ in accordance with [1.3.4] and [1.3.5].

a) Cargo and slop tanks of oil tankers.
b) Fore peak and aft peak ballast tanks.
c) Other tanks which allow free movement of liquid, e.g. ballast tanks, fuel oil bunkering tanks and fresh water tanks, etc.

Where the effective sloshing length, l_{slh} is less than 0.03 L, calculations involving $P_{slh\text{-}lng}$ are not required and where the effective sloshing breadth b_{slh} is less than 0.32 B, calculations involving $P_{slh\text{-}t}$ are not required.

1.3.2 Minimum sloshing pressure

The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in Ch 4, Sec 6, [6.2] is to apply to tanks in which the effective sloshing length, l_{slh} or breadth b_{slh}, is less than defined in [1.3.1].

1.3.3 Structural members to be assessed

The following structural members are to be assessed:

a) Plates and stiffeners forming boundaries of tanks.
b) Plates and stiffeners on wash bulkheads.
c) Web plates and web stiffeners of primary supporting members located in tanks.
d) Tripping brackets supporting primary supporting members in tanks.

1.3.4 Application of design sloshing pressure due to longitudinal liquid motion

The design sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, as defined in Ch 4, Sec 6, [6.3.3] is to be applied to the following members as shown in Figure 1.

a) Transverse tight bulkheads.
b) Transverse wash bulkheads.
c) Stringers on transverse tight and wash bulkheads.
d) Plating and stiffeners on the longitudinal bulkheads, deck and inner hull within a distance from the transverse bulkhead taken as:
   - 0.25 l_{slh},
   - The distance between the transverse bulkhead and the first web frame if located inside the tank at the considered level,

   whichever is less.

In addition, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25l_{slh} from the bulkhead, as shown in Figure 1, is to be assessed for the web frame reflected sloshing pressure, $P_{slh\text{-}wf}$, as defined in Ch 4, Sec 6, [6.3.4].

The minimum sloshing pressure, $P_{slh\text{-}min}$ as defined in Ch 4, Sec 6, [6.2] is to be applied to all other members.

1.3.5 Application of design sloshing pressure due to transverse liquid motion

The design sloshing pressure due to transverse liquid motion, $P_{slh\text{-}t}$, as defined in Ch 4, Sec 6, [6.4.3], is to be applied to the following members as shown in Figure 2.

a) Longitudinal tight bulkhead.
b) Longitudinal wash bulkhead.
c) Horizontal stringers on longitudinal tight and wash bulkheads.
d) Plating and stiffeners on the transverse tight bulkheads including stringers and deck within a distance from the longitudinal bulkhead taken as:
   - 0.25 b_{slh}
   - The distance between the longitudinal bulkhead and the first girder if located inside the tank at the considered level,

   whichever is less.

In addition, the first girder next to the longitudinal tight or wash bulkhead if the girder is located

within 0.25 b_{slh} from the longitudinal bulkhead, as shown in Figure 2, is to be assessed for the reflected sloshing pressure, $P_{slh\text{-}grd}$ as defined in Ch 4, Sec 6, [6.4.4].

The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in Ch 4, Sec 6, [6.2], is to be applied to all other members.

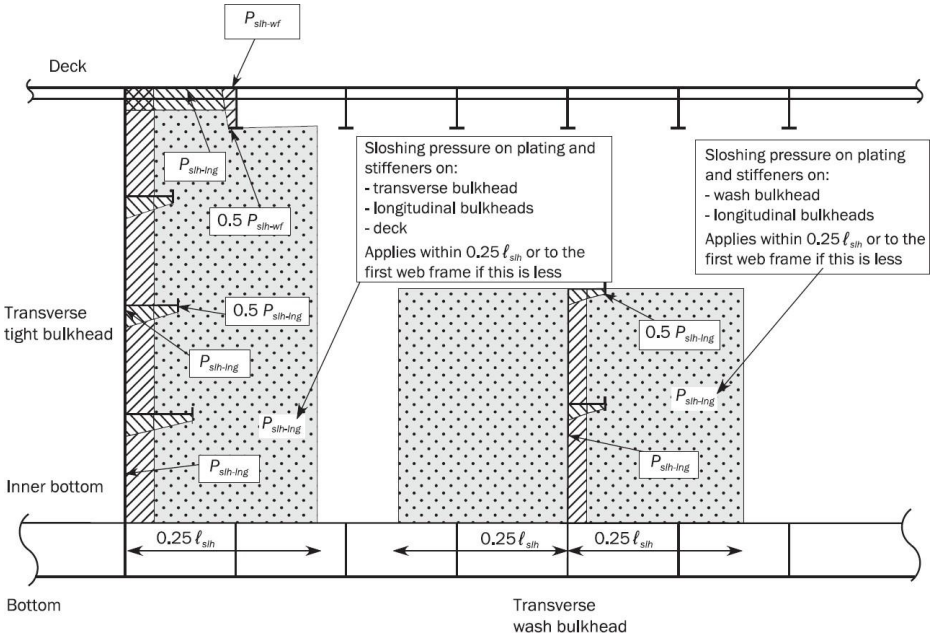


Figure 1 Application of sloshing loads due to longitudinal liquid motion

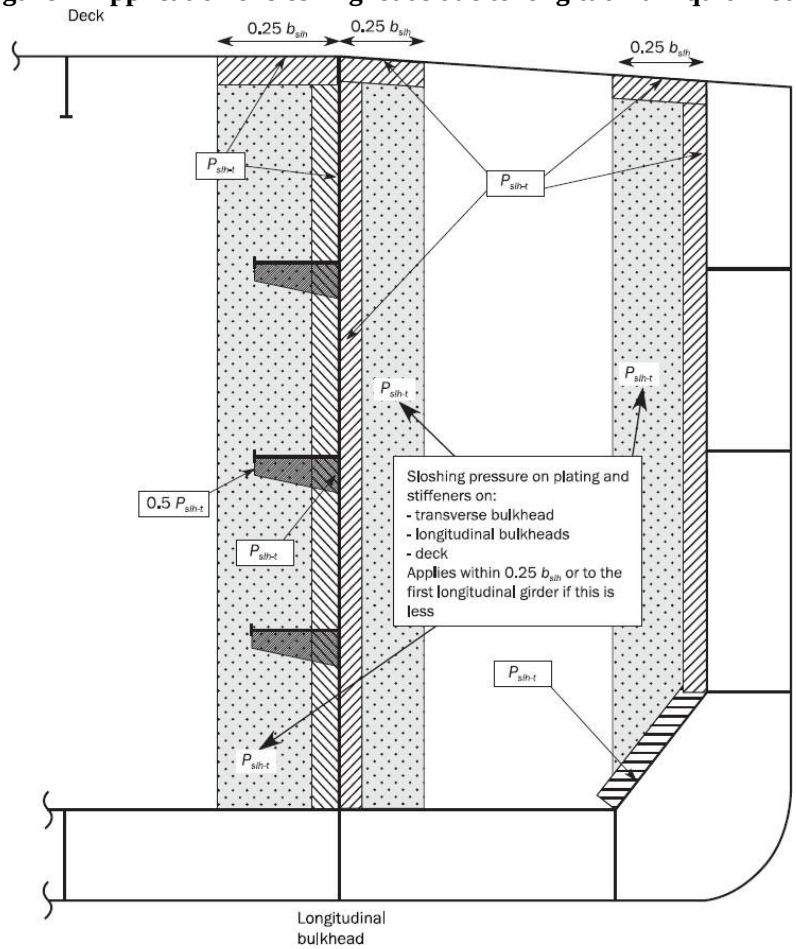


Figure 2 Application of sloshing loads due to transverse liquid motion

1.3.6 Combination of transverse and longitudinal fluid motion

The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

1.3.7 Additional sloshing impact assessment

For tanks with effective sloshing breadth, b_{slh}, greater than 0.56B or effective sloshing length, l_{slh}, greater than 0.13L, an additional sloshing impact assessment is to be carried out in accordance with the individual Society's procedures

ISC 1.3.7a Where l_s>0.13L or b_s>0.56B for the tank, the structural strength assessment under level 3 sloshing loads is to be carried out in accordance with relevant requirements of Section 3 of ISC Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

2 SCANTLING REQUIREMENTS

2.1 Plating

2.1.1 Net thickness

The net thickness of plating, t in mm, subjected to sloshing pressures is not to be less than:

$$t = 0.0158\alpha_p b\sqrt{\frac{P_{slh}}{C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient to be taken as:

$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$ with coefficients defined in Table 1, but not to be taken greater than $C_{a\text{-}max}$.

σ_{hg} : Hull girder bending stress, in N/mm^2, corresponding to the greatest of the sagging and hogging bending moment in absolute value.

P_{slh} : The greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

Definition β_a, α_a and $C_{a\text{-}max}$ **Table 1**

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-S	Longitudinal strength members in the cargo hold region including but not limited to: • Deck. • Longitudinal plane bulkhead. • Horizontal corrugated longitudinal bulkhead. • Longitudinal girders and stringers.	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other strength members including: • Vertical corrugated longitudinal bulkhead. • Transverse plane bulkhead. • Transverse corrugated bulkhead. • Transverse stringers and web frames. • Plating of tank boundaries and primary supporting members outside the cargo hold region.		0.8	0	0.8

2.2 Stiffeners

2.2.1 Net section modulus

The net section modulus, Z in cm^3, of stiffeners subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} : Bending moment factor:

f_{bdg} = 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners.

f_{bdg} = 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be

applied to discontinuous stiffeners.

C_s : Permissible bending stress coefficient to be taken as:

- For members subject to hull girder stress: coefficient to be taken as defined in Table 2.
- $C_s = C_{s\text{-}max}$ for other cases.

P_{slh} : The greater of $P_{slh\text{-}ing}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

$C_{s\text{-}max}$: Coefficient as defined in Table 3.

Permissible bending stress coefficient C_s **Table 2**

Sign of hull girder bending stress, σ_{hg} (1)	Lateral pressure acting on (2)	Stiffener boundary condition (3)	f_{bdg}	Coefficient C_s
Tension (positive)	Stiffener side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (negative)	Stiffener side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$

(1) σ_{hg} is to be considered for the hogging and sagging situations.
(2) For primary supporting members located inside the considered tank and for wash bulkheads, the sloshing pressure is to be applied both on stiffener and plate sides.
(3) F - F stands for both ends of the stiffener fixed against rotation
(4) F - S stands for one end of the stiffener fixed and the other not fixed against rotation
(5) S - S stands for both ends of the stiffener not fixed against rotation

Definition β_s , α_s and $C_{s\text{-}max}$ **Table 3**

Acceptance criteria set	Structural member		β_s	α_s	$C_{s\text{-}max}$
AC-S	Longitudinal strength members in the cargo hold region including but not limited to: • Deck stiffeners. • Stiffeners on longitudinal bulkheads. • Stiffeners on longitudinal girders and stringers.	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: • Stiffeners on transverse bulkheads. • Stiffeners on transverse stringers and web frames. • Stiffeners on tank boundaries and primary supporting members outside the cargo hold region.		0.75	0	0.75

2.3 Primary supporting members

2.3.1 Web plating

The web plating net thickness of primary supporting members, t in mm, is not to be less than:

$$t = 0.0158\alpha_p b\sqrt{\frac{P_{slh}}{C_a R_{eH}}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [4.1], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_a : Permissible plate bending stress coefficient, as given in [2.1.1].

2.3.2 Stiffeners on web plating

The net section modulus, Z in cm3, of each individual stiffener on the web plating of primary supporting members subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [3.2], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_s : Permissible bending stress coefficient as given in [2.2.1].

f_{bdg} : Bending moment factor as given in [2.2.1].

2.3.3 Tripping brackets supporting primary supporting members

The net section modulus, Z in cm^3 in way of the base within the effective length, d, of tripping brackets and net shear area, A_{shr} in cm^2, after deduction of cut-outs and slots, of tripping brackets supporting primary supporting members is not to be less than:

$$Z = \frac{1000 P_{slh} s_{trip} h^2}{2 C_s R_{eH}}$$

$$A = 10\frac{P_{slh} s_{trip} h}{C_t \tau_{eH}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown Figure 1 and Figure 2.

s_{trip} : Mean spacing, between tripping brackets or other primary supporting members or bulkheads, in m.

h : Height of tripping bracket, see Figure 3, in m.
C_s : Permissible bending stress coefficient for tripping brackets to be taken as 0.75.
C_t : Permissible shear stress coefficient for tripping brackets to be taken as 0.75.
The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket is to be taken as h/3.

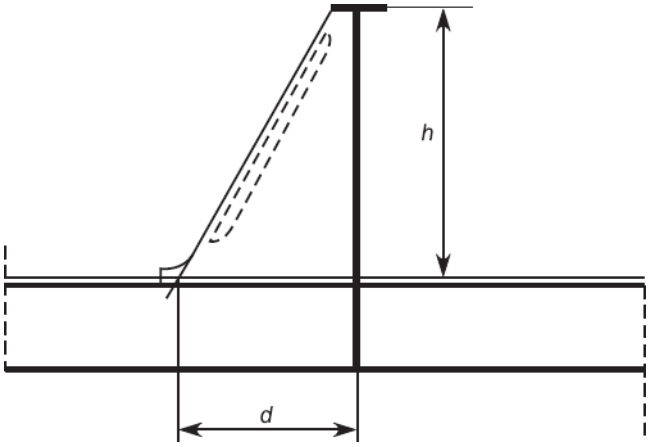


Figure 3 Effective length of tripping bracket

Chapter 11 SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING

Section 1 SUPERSTRUCTURES AND DECKHOUSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Pressure applied on the considered superstructure side or deck, in kN/m^2

$P = P_D$ for exposed decks,

$P = P_{dl}$ for unexposed deck,

$P = P_{SI}$ for superstructure side.

P_D : Lateral pressure for exposed decks, in kN/m^2, as defined in Ch 4, Sec 5, [2] and in Ch 4, Sec 5, [4.2].

P_{dl} : Lateral pressure for unexposed decks, in kN/m^2, as defined in Ch 4, Sec 6, [5].

P_{SI} : Lateral pressure for superstructure side, in kN/m^2, as defined in Ch 4, Sec 5, [4.3].

P_{FB}: Lateral pressure for side shell plating, in kN/m^2, affected by bow impact requirements according to Ch 4, Sec 5, [3.3.1].

P_A : External pressure for end bulkheads of superstructure and deckhouse walls, in kN/m^2 according to Ch 4, Sec 5, [4.4.1].

l_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7.

l_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7.

c : Coefficient taken as:

$c = 0.75$ for beams, girders and transverses which are simply supported in one or both ends.

$c = 0.55$ in other cases.

m_a : Coefficient taken as:

$$m_a = 0.204 \frac{s}{1000 l_{bdg}} \left[4 - \left(\frac{s}{1000 l_{bdg}} \right)^2 \right] \text{ with } \frac{s}{1000 l_{bdg}} \leq 1$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section are applicable to superstructures and deckhouses made of steel. The scantling requirements are listed in Table 1.

Applicable requirements **Table 1**

Item	Superstructure	Deckhouse
Exposed decks	[3.1.1]	[3.2]
Unexposed decks	[3.2.2] to [3.2.5]	[3.2]
Side walls	[3.1.1]	[3.3]
End bulkheads (fore and aft)	[3.3]	[3.3]

1.1.2

For the application of this section, a superstructure is considered being located aft or forward 0.4L amidships or having a length of less than 0.15 L.

1.1.3

For the application of this section, the length of a deckhouse located within 0.4 L amidships is considered not exceeding 0.2 L.

1.2 Gross scantlings

1.2.1

With reference to Ch 3, Sec 2, [1.1.3], all scantlings and dimensions referred to in [3] are gross, unless otherwise specified.

2 STRUCTURAL ARRANGEMENT

2.1 Structural continuity

2.1.1 Bulkheads and sides of deckhouses

The aft, front and side bulkheads are to be effectively supported by under deck structures such as bulkheads, girders and pillars.

Sides and main longitudinal and transverse bulkheads are to be in line in the various tiers of deckhouses. Where such arrangement in line is not possible, other effective support is to be provided.

Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides are to be framed and have well-rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

2.1.2 Deckhouse corners

At the corners where the deckhouse is attached to the strength deck, attention is to be given to the arrangements to transmit load into the under deck supporting structure.

2.2 End connections

2.2.1 Deck stiffeners

Transverse beams are to be connected to side frames by brackets according to Ch 3, Sec 6, [3.2.1], [3.2.2] and [3.2.3]. Beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Longitudinal and transverse deck girders

Face plates are to be stiffened by tripping brackets according to Ch 3, Sec 6, [4.3].

2.2.3 End connections of superstructure frames

Vertical frames are to be welded to the main frames below, or to the deck under provision of a sufficient supporting structure.

2.3 Local reinforcement on bulkheads

2.3.1

Local reinforcement is to be provided in way of large openings and areas supporting life saving appliances or high loads from other equipment, fittings, etc.

3 SCANTLINGS

3.1 Superstructures sides and decks

3.1.1 Exposed sides and exposed decks

When the side of superstructure is part of the side shell, the net scantlings of exposed sides and exposed decks plating, stiffeners and primary supporting members are to comply with the applicable requirements of Ch 6, Sec 3, Ch 6, Sec 4, Ch 6, Sec 5 and Ch 6, Sec 6, respectively, with the pressure P_D , P_{dl} and P_{SI} defined in this Section. The net scantling approach defined in Ch 3, Sec 2 and the corrosion additions defined in Ch 3, Sec 3, are to be considered.

When the side of superstructure is not part of the side shell, the exposed sides and exposed deck plating inclusive their supporting structure are to comply with the requirements given in [3.3], [3.2.1] and [3.2.3] to [3.2.5], respectively.

3.2 Deckhouses decks

3.2.1 Exposed deck plating

The gross thickness of the deckhouses exposed deck plating, $t_{gr\text{-}exp}$, in mm, is not to be less than

$$t_{gr-\exp} = 7.5\sqrt{\frac{ks}{s_{std}}}$$, on first tier

$t_{gr-\exp} = 7.0\sqrt{\frac{ks}{s_{std}}}$, on second tier.

$t_{gr\text{-}\exp} = 6.5\sqrt{\frac{ks}{s_{std}}}$, on third tier and above.

where:

s_{std} *:* Standard reference spacing of stiffeners or beams, in mm, taken as:

$s_{std} = 470 + 1.67\ L_1$

Where deck is protected by sheathing, the gross thickness of the deck plating may be reduced by 1.5 mm, without being less than 5 mm.

Where sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

3.2.2 Unexposed deck plating

The gross thickness of the deckhouses unexposed deck plating, $t_{gr\text{-}unexp}$, in mm, is not to be less than the greater value of:

$t_{gr\text{-}unexp}=0.9t_{gr\text{-}exp}$, at the tier considered, and

$t_{gr\text{-}unexp} = (5.8\frac{s}{1000}+1)\sqrt{k}$, but not less than 5.5 mm.

3.2.3 Beams and stiffeners

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of deckhouses deck transverse beams and of stiffeners are not to be less than:

$$Z_{gr} = ckP\frac{s}{1000}l_{bdg}{}^2$$

$$A_{gr-sh} = 0.05(1-0.817m_a)kP\frac{s}{1000}l_{shr}$$

3.2.4 Girders and transverses

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of deckhouses deck girders and transverses are not to be less than:

$$Z_{gr} = ckPSl_{bdg}{}^2$$

$$A_{gr-sh} = 0.05kPSl_{shr}$$

The girder depth is not to be less than $l/25$. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 times the depth of the deck beams.

3.2.5 Alternative grillage analysis for girders and transverses

Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out with a structural model based on the gross scantling. The resulting stresses are not to exceed the following permissible bending, shear and equivalent stresses, in N/mm^2, taken as:

$\sigma_b=150/k$

$\tau=100/k$

$\sigma_{eqv}=180/k$

3.3 Deckhouses walls and end bulkheads of superstructures

3.3.1 Application

The requirements in [3.3] apply to end bulkhead of superstructure and deckhouse walls forming the only protection for openings and for accommodations.

Special consideration may be given to the bulkhead scantlings of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse. Special consideration may also be given to the bulkhead scantlings of deckhouses which do not

protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation of the ship.

ISC 3.3.1a The bulkheads scantling of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse are to comply with the requirements of [3.3.2] and [3.3.3]. The bulkheads scantlings of deckhouses which do not protect machinery casings are also to comply with the requirements of [3.3.2] and [3.3.3].

3.3.2 Plate thickness

The gross thickness of the plating t_{gr}, in mm, is not to be less than the greater of:

$$t_{gr} = 0.9 \frac{s}{1000} \sqrt{kP_A} + 1.5$$

$t_{gr} = (5.0 + \frac{L_2}{100}) \sqrt{k}$, for the lowest tier.

$t_{gr} = (4.0 + \frac{L_2}{100}) \sqrt{k}$, for the upper tiers, without being less than 5.0 mm.

3.3.3 Stiffeners

The gross section modulus Z_{gr}, in cm^3, of the stiffeners is not to be less than:

$$Z_{gr} = 0.35 k P_A \frac{s}{1000} l^2$$

This requirement assumes the webs of lowest tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections are to be specially considered.

The section modulus of deckhouse side stiffeners needs not to be greater than that of side frames on the deck situated directly below, taking account of spacing *s* and span *l*.

Section 2 BULWARK AND GUARD RAILS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1

Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks, at the boundary of first tier of deckhouses and at the ends of superstructures.

1.2 Minimum height

1.2.1

Bulwarks, or guard rails, are to be a minimum of 1.0 m in height, measured above sheathing, and are to be constructed as required in [2.2] and [3.2]. Where this height would interfere with the normal operation of the ship, a lesser height may be accepted, on the basis of justifying information to be submitted.

2 BULWARKS

2.1 General

2.1.1

Plate bulwarks are to be stiffened at the upper edge by a suitable rail and supported either by stays or plate brackets spaced not more than 2.0 m apart.

The free edge of the stay or the plate bracket is to be stiffened.

2.1.2

Within 0.6 *L* amidships, bulwarks are to be arranged to ensure that they are free from hull girder stresses.

2.1.3

Bulwarks are to be adequately strengthened and increased in thickness in way of mooring pipes.

Cut-outs in bulwarks for gangways or other openings are to be kept clear of breaks of superstructures.

2.1.4

Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.1.5

Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.1.6

In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

2.1.7

Where mooring fittings subject the bulwark to large forces, the stays are to be adequately strengthened.

2.2 Construction of bulwarks

2.2.1 Plating

The gross thickness of bulwark plating, at the boundaries of exposed freeboard and superstructure decks, is not to be less than that given in Table 1.

2.2.2 Stays

The gross section modulus of stays, $Z_{stay-gr}$, in cm^3, is not to be less than:

$$Z_{stay-gr} = 77 h_{blwk}{}^2 s_{stay}$$

where:

h_{blwk} : Height of bulwark from the top of the deck plating to the top of the rail, in m.

s_{stay} : Spacing of the stays, in m.

In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck. Where the bulwark plating is connected to the sheer strake, a width of attached plating, not exceeding 600 mm, may also be included.

Thickness of bulwark plates **Table 1**

Height of bulwark	Gross thickness
1.8 m or more	Thickness required for a superstructure side in the same position, obtained from Ch11, Sec 1 [3.2.1], but not to be less than 6.5 mm
1.0 m	6.5 mm
Intermediate height	To be determined by linear interpolation

2.2.3

Where bulwarks are cut completely, stays or plate brackets of increased strength are to be fitted at the ends of openings.

Bulwark stays are to be supported by, or are to be in line with, suitable under deck stiffening. The stiffening is to be connected by double continuous fillet welds in way of bulwark stay connections.

2.2.4

At the ends of superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating. Where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

3 GUARD RAILS

3.1 General

3.1.1

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

3.1.2

In Type B-100 and Type A ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with ICLL are to be fitted.

3.2 Construction of guard rails

3.2.1

Stanchions of guard rails are to comply with the following requirements:

a) Fixed, removable or hinged stanchions are to be fitted approximately 1.5 m apart.
b) At least every third stanchion is to be supported by a bracket or stay.
c) Removable or hinged stanchions are to be capable of being locked in the upright position.
d) In the case of ships with rounded sheer strake, the stanchions are to be placed on the flat of the deck.
e) In the case of ships with welded sheer strake, the stanchions are not to be attached to the sheer strake, upstand or a continuous gutter bar.

3.2.2

The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

3.2.3
Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

3.2.4
Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks. if the opening is wide, the chains are to be fitted with vertical courses to prevent the horizontal courses from spreading apart.

Section 3 EQUIPMENT

SYMBOLS
DELETED

1 GENERAL

1.1 Application

1.1.1
Anchoring equipment shall be considered by individual Society.

ISC 1.1.1a Anchoring equipment is to comply with the requirements of PART TWO, Ch 3, Sec 2 of ISC Rules for Classification of Sea-going Steel Ships.

Section 4 SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS

SYMBOLS
DELETED

1 GENERAL

1.1 Application

1.1.1
The supporting structure and foundations for deck equipment and fittings shall be considered by individual Society in addition to the requirements in this section.

ISC 1.1.1a In addition to the requirements of this section, the supporting structure and foundations for deck equipment and fittings are to comply with the requirements of PART TWO, Ch 3, Sec 6 of ISC Rules for Classification of Sea-going Steel Ships. The corrosion addition shall comply with the requirements of Ch 3, Sec 3 of this part.

1.1.2
Where deck equipment is subject to multiple load cases, such as operational loads and green sea load, the loads are be applied independently for the evaluation of strength of foundations and support structure.

1.2 Documents to be submitted

1.2.1
The documents to be submitted are indicated in Ch 1, Sec 3.

2 ANCHORING WINDLASS AND CHAIN STOPPER

2.1 General

2.1.1
The windlass is to be efficiently bedded and secured to the deck.

2.1.2
The builder and the windlass manufacturer are to ensured that the foundation is suitable for the safe operation and maintenance of the windlass equipment.

2.1.3
The supporting structure is to be dimensioned to ensure that for each of the load scenarios specified in [2.1.5] and [2.1.6], the stresses do not exceed the permissible values given in [2.1.12] to [2.1.15].

ISC 2.1.3a For the strength check of supporting structure and foundation, a three-dimensional FE model may be applied in the analysis. The principles for extent, element types and boundary conditions of a three- dimensional model are as follows:

(1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle (a×b) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle (3a ×3b). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least D/4 (D being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.

(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in Section 1 of Chapter 7.

ISC 2.1.3b In accordance with the design load of 2.1.3, the allowable equivalent stress of plate

element $[\sigma_e] = 1.00R_{eH.}$
where:
R_{eH} *– yield stress of material, in N/mm*^{2}.

2.1.4
These requirements are to be assessed based on net scantlings.

2.1.5
The following load cases are to be examined for the anchoring operation, as appropriate:

a) Windlass where chain stoppers are fitted but not attached to the windlass is provided: 45% of BS.
b) Windlass where no chain stopper is fitted or the chain stopper is attached to the windlass: 80% of BS.
c) Chain stopper: 80% of BS.

where:
BS : Minimum breaking strength of the chain cable.

2.1.6
The following forces are to be applied in the independent load cases that are to be examined for the design loads due to green sea over the forward 0.25 *L*, see Figure 1:
$P_x = 200\,A_x$, in kN, acting normal to the shaft axis.
$P_y = 150\,A_y\,f$, in kN, acting parallel to the shaft axis (inboard and outboard directions to be examined separately).
where:
A_x : Projected frontal area, in m^2.
A_y : Projected side area, in m^2.
f : Coefficient taken as:
$f = 1 + B_w/H$, but not to be taken greater than 2.5.
B_w : Breadth of windlass measured parallel to the shaft axis, in m, see Figure 1.
H : Overall height of windlass, in m, see Figure 1.

2.1.7
Forces resulting from green sea design loads in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by a number of bolt groups, *N*, each containing one or more bolts. See Figure 2.

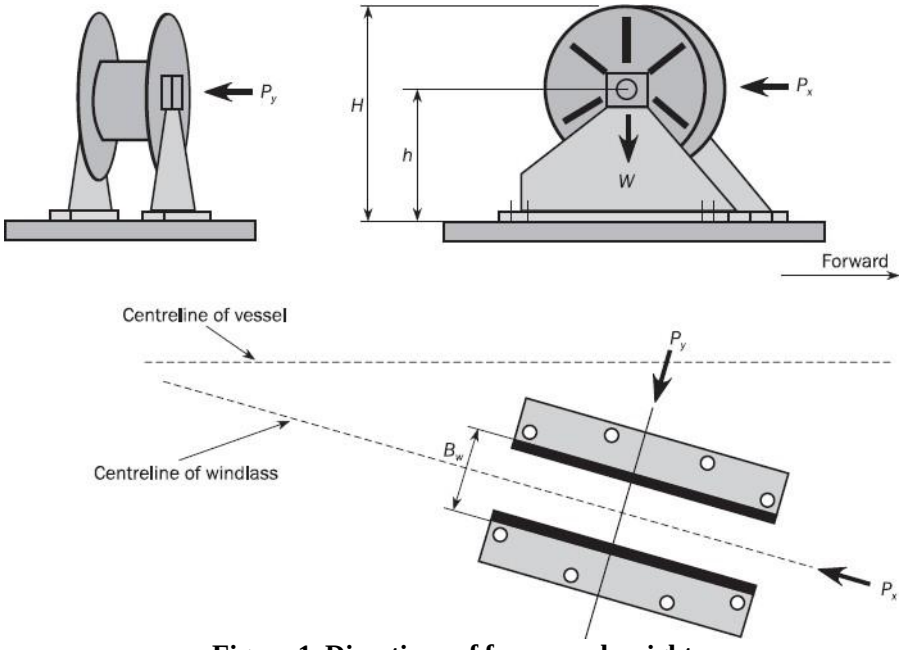


Figure 1 Directions of forces and weight

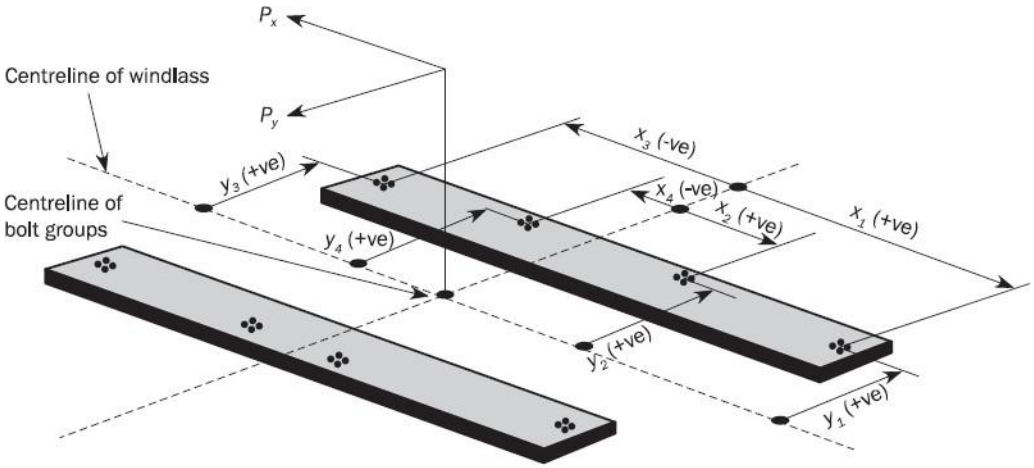


Figure 2 Bolting arrangements and sign conventions

2.1.8

The axial forces, *Rxi* and *Ryi*, in bolt group (or bolt) *i*, positive in tension, are given by:

$$R_{xi} = P_x hx_i A_i / I_x$$

$$R_{yi} = P_y hy_i A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where:

P_x : Force acting normal to the shaft axis, in kN.

P_y : Force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group *i*, in kN.

h : Shaft centre height above the windlass mounting, in cm, see Figure 1.

x_i, y : x and y coordinates of bolt group *i* from the centroid of all *N* bolt groups, in cm. Positive in the direction opposite to that of the applied force.

A_i : Cross sectional area of all bolts in group *i*, in cm^2.

I_x : Inertia in x direction for *N* bolt groups, in cm^4, taken as:

$I_x = \Sigma A_i x_i^2$

I_y : Inertia in y direction for *N* bolt groups, in cm^4, taken as:

$I_y = \Sigma A_i y_i^2$

R_{si} *:* Static reaction at bolt group *i*, due to the weight of windlass, in kN.

2.1.9

The shear forces, F_{xi} and F_{yi}, applied to the bolt group *i*, and the resultant combined force F_i, are given by:

$$F_{xi} = (P_x - C_1 mg) / N$$

$$F_{yi} = (P_y - C_1 mg) / N$$

$$F_i = \sqrt{F_{xi}^2 + F_{yi}^2}$$

where:

C_1 : Coefficient of friction, taken equal to 0.5.

m : Mass of windlass, in t.

g : Acceleration due to gravity, taken equal to 9.81 m/s^2.

N : Number of bolt groups.

2.1.10

The resultant forces from the application of the loads specified in [2.1.5] and [2.1.6] are to be considered in the design of the supporting structure.

2.1.11

Where a separate foundation is provided for the windlass brake, the distribution of resultant forces is to be calculated on the assumption that the brake is applied for load cases (a) and (b) defined in

[2.1.5].

2.1.12
The stresses resulting from anchoring design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}
- Shear stress, 0.6 R_{eH}

2.1.13
The tensile axial stresses resulting from green sea design loads in the individual bolts in each bolt group *i* are not to exceed 50% of the bolt proof strength. The load is to be applied in the direction of the chain cable. Where fitted bolts are designed to support shear forces in one or both directions, the von Mises equivalent stresses are not to exceed 50% of the bolt proof strength.

2.1.14
The horizontal forces resulting from the green sea design loads, F_{xi} and F_{yi} may be supported by shear chocks. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculation.

2.1.15
The stresses resulting from green sea design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.6 R_{eH}.

3 CRANES, DERRICKS, LIFTING MASTS AND LIFE SAVING APPLIANCES

3.1 General

3.1.1
Supporting structure of life saving appliances and supporting structures of cranes, derricks and lifting masts with a Safe Working Load greater than 30kN, or a maximum overturning moment to the supporting structure greater than 100kNm, are to comply with these requirements.

3.1.2
These requirements apply to the connection to the deck and the supporting structure of cranes, derricks and lifting masts. Where the crane, derrick or lifting mast is to be certified by the Society, additional requirements may be applied by the Society.

ISC 4.1.2a In addition to the requirements of 4.1.2, the applicable requirements of Section 10, Chapter 3 of ISC Rules for Lifting Appliances of Ships and Offshore Installations are also to be complied with.

3.1.3
These requirements do not cover the following items:

a) Supports of lifting appliances for personnel or passengers, except foundation for life saving appliances.
b) The structure of the lifting appliance pedestals or post above the area of the deck connection.
c) Holding down bolts and their arrangement, which are considered part of the lifting appliance. The term 'lifting appliance' is defined as a crane, derrick or lifting mast.

3.1.4 SWL Definition
The Safe Working Load (SWL) is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

3.1.5 Self weight
The self weight is the calculated gross self weight of the lifting appliance, including the weight of

any lifting gear.

3.1.6 Overturning moment

The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at Safe Working Load, taking into account outreach and self weight.

3.1.7

The crane pedestal and derrick mast are as defined in Figure 3.

3.1.8

Deck plating and under deck structure is to provide adequate support for derrick masts and crane pedestals against the loads and maximum overturning moment. Where the deck is penetrated, the deck plating is to be suitably strengthened.

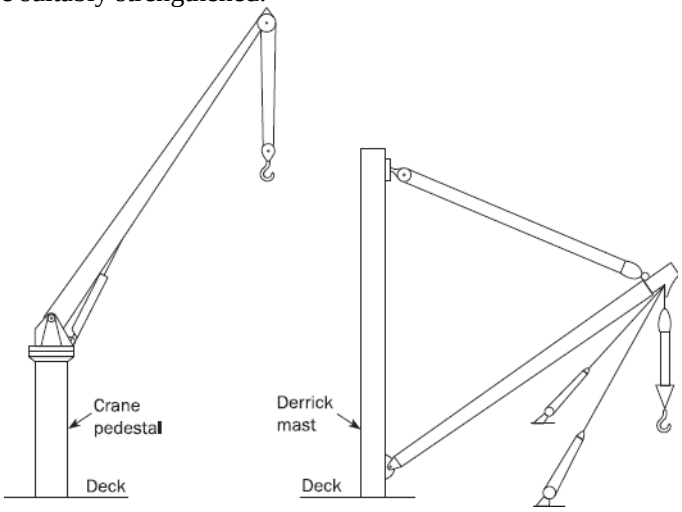


Figure 3 Crane pedestal and derrick mast

3.1.9

Structural continuity of the deck structure is to be maintained.

Under deck members are to be provided to support the crane pedestal and to comply with:

a) Where the pedestal is directly connected to the deck, without above deck brackets, adequate under deck structure directly in line with the crane pedestal is to be provided. Where the crane pedestal is attached to the deck without bracketing or where the crane pedestal is not continuous through the deck, welding to the deck of the crane pedestal and its under deck support structure is to be made by suitable full penetration welding. The design of the weld connection is to be adequate for the calculated stress in the welded connection, in accordance with [3.1.15].

b) Where the pedestal is directly connected to the deck with brackets, under deck support structure is to be fitted to ensure a satisfactory transmission of the load, and to avoid structural hard spots. Above deck brackets may be fitted inside or outside of the pedestal and are to be aligned with deck girders and webs. The design is to avoid stress concentrations caused by an abrupt change of section. Brackets and other direct load carrying structure and under deck support structure are to be welded to the deck by suitable full penetration welding. The design of the connection is to be adequate for the calculated stress, in accordance with [3.1.15].

3.1.10

Deck plating are to be of a material strength compatible with the crane pedestal. Where necessary, a thicker insert plate is to be fitted. In no case are doublers to be used where structures are subject to tension.

3.1.11

The supporting structure is to be dimensioned to ensure that for the load cases specified in [3.1.13] and [3.1.14], the stresses do not exceed those given in [3.1.15].

The capability of the supporting structure to resist buckling failure is to be assured.

ISC 4.1.11a In accordance with the design load of 4.1.11, a three-dimensional FE model may be applied in the analysis for the supporting structure in accordance with [ISC 2.1.3a]. The allowable equivalent stress, $[\sigma_e] = 0.8R_{eH}$, where: R_{eH} – yield stress of material, in N/mm^2.

3.1.12
These requirements are to be assessed based on gross scantlings.

3.1.13
For lifting appliances which are limited to use in harbour, design load is to be taken equal to 1.3 times SWL added to the lifting appliances self weight.

3.1.14
For life saving appliances, design load is to be taken as 2.2 times SWL.

3.1.15
The stresses induced in the supporting structure are not to exceed the following permissible values:

- Normal stress, 0.67 R_{eH}
- Shear stress, 0.39 R_{eH}

4 MISCELLANEOUS DECK FITTINGS

4.1 Support and attachment

4.1.1
The following requirements are to be considered in the design of the support and attachment of miscellaneous fittings which impose relatively small loads on the ship's structure. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

ISC 6.1.1a The strength assessment is carried out to the supporting structure of other deck equipment in accordance with the strength analysis method and criteria of this Section based on the design load submitted by the manufacturer.
ISC 6.1.1b For the connection structures of hull outfitting equipment to the deck, it is to be noted that:

(1) For the supporting structures of pipelines, open type sections (e.g. T, L, I, X etc.) are used and the corresponding supporting structures are strengthened by using web plates, collar plates and backing brackets. Ring support is used for large pipelines.
(2) Where pipelines pass through the deck, seamless casing pipes or those with welds ground are used to assist pipelines passing through the deck.
(3) Local transition is to be avoided in way of the backing strengthening under the deck. Transition is to made from the structure to the stiffener or frame.
(4) Stress concentration or high stress areas are to be avoided for cut-outs such as manholes/hatches. The watertight manhole covers are to be such that their strength is equivalent to the local strength of the associated deck. The edge of cut-outs is to be ground smooth.

4.1.2
Support positions are to be arranged so that the attachment to the ship structure is clear of deck openings and stress concentrations, such as the toes of end brackets. Design of supports is to be such that the attachment to the deck minimises the creation of hard points.

Section 5 SMALL HATCHWAYS

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1
The requirements in [1.2] to [1.6] apply to small hatchways at weather deck in positions 1 and 2 as defined in Ch 1, Sec 4, [3.2]. The requirements in [2] apply to small hatchways fitted on the exposed fore deck over the forward 0.25 *L*.
Hatchways of bulk carriers not covered by the definition of small hatchways in [1.4.1] are to comply with applicable requirements in Pt 2, Ch 1.

1.2 Materials

1.2.1
Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

ISC 1.2.1a Materials used for the construction of small steel hatch covers are to comply with the applicable requirements of Chapter 3, PART ONE of ISC Rules for Materials and Welding.

1.2.2
The use of materials other than steel is considered by the Society on a case-by-case basis.

ISC 1.2.2a Small *hatch covers constructed of materials other than steel are to provide a strength equivalent to that of small steel hatch covers.*

1.3 Height of hatch coamings

1.3.1
The height above the deck of hatch coamings is not to be less than:

- 600 mm in position 1.
- 450 mm in position 2.

1.3.2
The height, given in [1.3.1], of hatch coamings closed by steel covers provided with gaskets and securing devices may be reduced or the coamings may be omitted entirely, on condition that the Flag Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.
In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

ISC 1.3.2a Subject to the agreement of the flag Administration, the height of hatch coamings may be appropriately reduced provided that the safety of the ship is not thereby impaired and that effective measures are taken. In this case, the scantlings of the hatch covers are to comply with the requirements of 2.2. The arrangement of sealing gasket and securing devices is to comply with the relevant requirements of this Section, taking into account the strength and arrangement of pressure head, stoppers and securing devices as well as factors such as the effectiveness of drainage and sealing materials.

1.4 Small hatchways

1.4.1
Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2.5 m^2.
Hatch covers on exposed decks are to be weathertight.

Hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

1.4.2
Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition. At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

1.4.3
Hatchways of special design are considered by the Society on a case-by-case basis.

ISC 1.4.3a The design of special securing arrangement and the rigidity of edge of hatch covers is to take into account the strength and arrangement of pressure head, stoppers and securing arrangement as well as factors such as the effectiveness of drainage measures and sealing materials.

1.4.4
The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening is to be fitted where the greatest horizontal dimension of the cover exceeds 0.6 m.

1.4.5
The gross thickness of coaming plate is not to be less than the lesser of the following values:

- The gross thickness for the deck in way of hatch coaming, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners.
- 10 mm.

Coamings are to be strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

1.5 Cargo tank access hatchways

1.5.1
Requirements given in [1.2] to [1.4] have to be considered as minimum requirements for cargo tank hatchways.
The requirements of [1.5.4] do not apply to dished covers or covers of other specially approved design.

1.5.2
Covers for access hatches, tank cleaning and other openings for cargo tanks and adjacent spaces are to be manufactured from the following material:

a) Normal strength steel in accordance with Ch 3, Sec 1.
b) Non-ferrous material may be considered, such as bronze or brass. Aluminium alloy is not to be used for covers of any opening to cargo tanks and spaces adjacent thereto.
c) Synthetic materials may be considered, taking into account their fire resistance and their physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover, and the method of manufacture are to be submitted for approval.

The hatch cover packing material is to be compatible with the cargoes that are intended to be carried and is to be effectively held in place.

1.5.3
The height of the hatch coaming above the upper surface of the freeboard deck is not to be less than 600 mm. Lower heights may be permitted by the Flag Administration. In addition, the top of the hatch coaming is not to be lower than the highest point of the tank over which it is fitted and is to be of sufficient height for the purpose of damage stability.
The gross thickness of the coaming plate is not to be less than 10 mm. Where the coaming height, as fitted, exceeds 600 mm, the thickness may be required to be increased or edge stiffening fitted. The scantlings of coaming plates of tank access coamings that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, may be subject to additional

requirements.

ISC 1.5.3a For the coaming plates of tank access small hatchways that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, stiffeners are to be fitted on the hatch coaming. The thickness of hatch coaming and the stiffeners on the coaming plate are to comply with the requirements of 6.3.1 and 6.3.2, Section 5, Chapter 1 of PART 9-2.

1.5.4
The gross thickness of unstiffened plate covers with an area less than 1.2 m^2 is not to be less than 12.5 mm. The gross thickness of covers of a larger area will need to be increased or the cover will require stiffening.
Flat and unstiffened covers on circular hatchways are to be secured by fastenings with a spacing of not more than 600 mm.
On rectangular hatchways, the spacing of fastenings is generally not to be greater than 450 mm and the distance between hatch corners and adjacent fastenings is not to be greater than 230 mm.
Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be considered securing devices for the cover and are to be designed so as to prevent the gasket from being over-tightened.

1.6 Gaskets
1.6.1
The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

1.6.2
Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2 SMALL HATCHWAYS FITTED ON THE EXPOSED FORE DECK

2.1 General
2.1.1
These requirements apply to small hatchways (generally openings 2.5 m^2 or less) on the exposed deck within 0.25 *L* from the FP and located at a height less than 0.1 *L* or 22 m, whichever is less, from the summer load water line at the location of the hatch.

2.1.2
Hatchways designed for emergency escape need not comply with the requirements [2.3.1] items (a) and (b), [2.4.3] and [2.5.1].

2.1.3
Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

2.2 Strength
2.2.1
For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Table 1 and Figure 2. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [2.4.1] and shown in Figure 2. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.

Gross scantlings for small steel hatch covers on the fore deck **Table 1**

Nominal size, in mm	Cover plate thickness, in mm	Primary stiffeners	Secondary stiffeners
		Flat bar size, in mm ; number of stiffeners	
630 ×630	8	-	-
630 ×630	8	100 ×8 ; 1	-
830 ×630	8	100 ×8 ; 1	-
830 ×630	8	100 ×10 ; 1	-
1030 ×1030	8	120 ×12 ; 1	80 ×8 ; 2
1330 ×1330	8	150 ×12 ; 2	100 ×10 ; 2

2.2.2
The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal member, normally not more than 190 mm from the upper edge of the coaming.

2.2.3
For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

2.2.4
For small hatch covers constructed of materials other than normal strength steel, the required scantlings are to provide equivalent strength and stiffness.

2.3 Primary securing devices
2.3.1
The primary securing devices are to be fitted such that the hatch cover can be secured in place and be made weathertight by means of a closing mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps),
b) Quick acting cleats, or
c) A central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

2.4 Requirement to primary securing
2.4.1
The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 2 and of sufficient capacity to withstand the bearing force.

2.4.2
The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

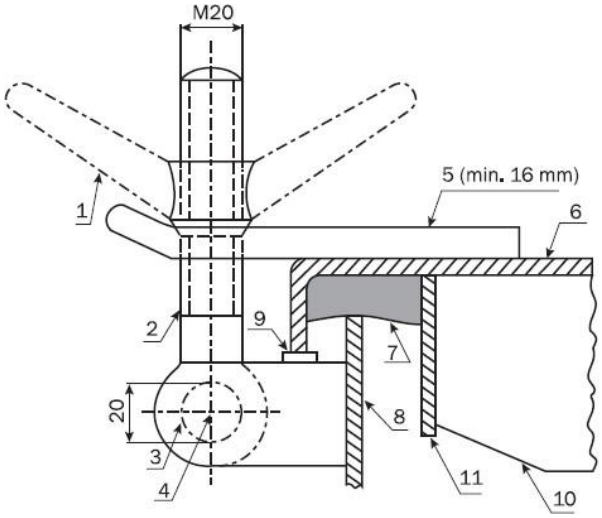
2.4.3
For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Figure 1.

2.4.4
For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to

close, which means that the hinges are normally to be located on the fore edge.

2.4.5
On small hatches located between the main hatches, for example between No. 1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

2.5 Secondary securing devices
2.5.1
Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.



1. Butterfly nut
2. Bolt
3. Pin
4. Centre of pin
5. Fork (clamp) plate
6. Hatch cover
7. Gasket
8. Hatch coaming
9. Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. Stiffener
11. Inner edge stiffener

(Note: Dimensions in millimetres)

Figure 1: Example or primary securing device

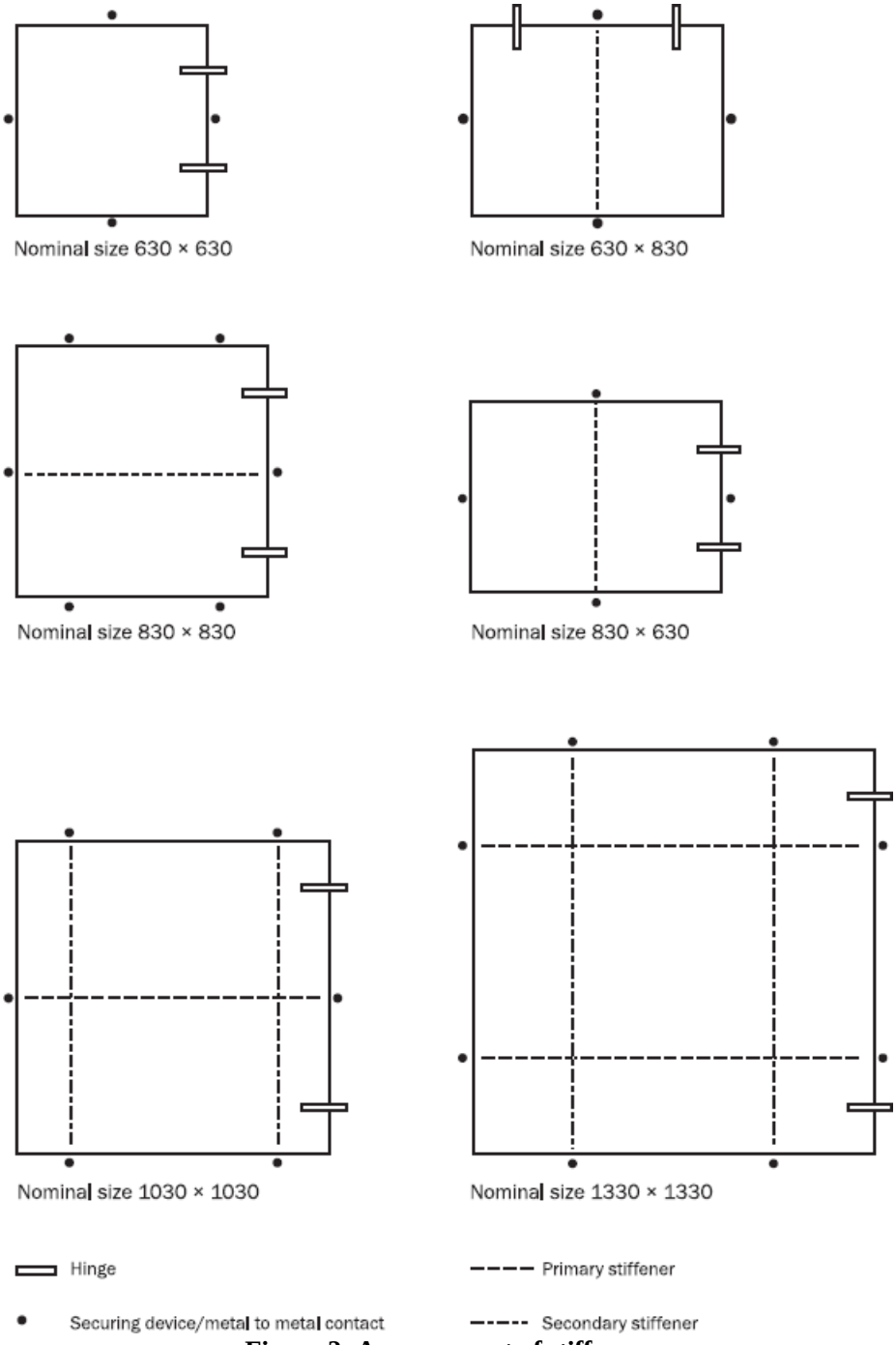


Figure 2: Arrangement of stiffeners

Chapter 12 CONSTRUCTION

Section 1 CONSTRUCTION AND FABRICATION

1 GENERAL

1.1 Workmanship

1.1.1

All workmanship is to be of commercial marine quality and acceptable to the surveyor. Welding is to be in accordance with the requirements of Ch 12, Sec 2. Any defect is to be rectified to the satisfaction of the surveyor before the material is covered with paint, cement or any other composition.

1.2 Fabrication standard

1.2.1

Structural fabrication is to be carried out in accordance with IACS Recommendation No. 47 or with a recognised fabrication standard which has been accepted by the Society prior to the commencement of fabrication /construction.

ISC 1.2.1a Where other standards are used by the shipyard, documents are to be provided by the shipyard to demonstrate that such standards are equivalent to IACS Recommendation No. 47.

1.2.2

The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Society prior to the commencement of the fabrication/construction.

1.2.3

The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

a) Cut edges: the slope of the cut edge and the roughness of the cut edges.
b) Flanged stiffeners and brackets and built-up sections: the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate.
c) Pillars: the straightness between decks and cylindrical structure diameter.
d) Brackets and flat bar stiffeners: the distortion at the free edge line of tripping brackets and flat bar stiffeners.
e) Sub-assembly stiffeners: details of sniped end of face plates and webs.
f) Plate assembly: for flat and curved blocks, the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate.
g) Cubic assembly: in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks.
h) Special assembly: the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece are to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognised by the Society. The fit-up and alignment of the rudder, pintles and axles are to be carried out after completing the major parts of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.
i) Butt joints in plating: alignment of butt joint in plating.
j) Cruciform joints: alignment measured on the median line and measured on the heel line of cruciform joints.
k) Alignment of interior members: alignments of flange of T profiles, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut-outs for

continuous stiffeners in assembly and in erection joints.

l) Keel and bottom sighting: deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships.
m) Dimensions: length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine.
n) Fairness of plating between frames: deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deckhouse deck and wall plating.
o) Fairness of plating in way of frames: deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames.

ISC 1.2.3a Where block boring is used, the shaft alignment is to comply with the relevant requirements of Section 5, Chapter 12, PART THREE MACHINERY of ISC Rules for Classification of Sea-going Steel Ships

2 CUT-OUTS, PLATE EDGES

2.1 General

2.1.1

The free edges (cut surfaces) of cut-outs, hatch corners, etc are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as specified above. This also applies to cutting drag lines, etc, in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.1.2

Corners in hatch opening are to be machine cut.

3 COLD FORMING

3.1 Special structural members

3.1.1

For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in Ch 3, Sec 1, Table 3, such as radius gunwales (bent sheer plates) and bilge strakes), the inside bending radius, in cold formed plating, is not to be less than 10 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.2 Corrugated bulkheads and hopper knuckles

3.2.1

For corrugated bulkheads and hopper knuckles, the inside bending radius, in cold formed plating, is not to be less than 4.5 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.3 Low bending radius

3.3.1

When the inside bending radius is reduced below 10 times or 4.5 times the as-built plate thickness according to [3.1] and [3.2] respectively, supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

a) or all bent plates:
   - 100% visual inspection of the bent area is to be carried out.
   - Random checks by magnetic particle testing are to be carried out.
b) In addition to a), for bent plates at boundaries to tanks or ballast holds:
   - The steel is to be of Grade D/DH or higher.

- The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built} /(2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4 HOT FORMING

4.1 Temperature requirements

4.1.1

Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 28°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with [4.2.1] these mechanical tests are not required.

4.1.2

After further heating, other than specified in [4.1.1], of Thermo-Mechanically Controlled Steels (TMCP plates) for forming and stress relieving, it is to be demonstrated that the mechanical properties meet the requirements specified by a procedure test using representative material.

4.2 Line or spot heating

4.2.1

Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature on the surface is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

5 ASSEMBLY AND ALIGNMENT

5.1 General

5.1.1

The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. Major distortions of individual structural components are to be corrected before further assembly.

After completion of welding, straightening and aligning are to be carried out in such a manner that the material properties are not influenced significantly. In case of doubt, the Society may require a procedure test or a working test to be carried out.

5.1.2

Structural members are to be aligned following the provisions of IACS Recommendation No. 47, Tables 7 or according to the requirements of a recognised fabrication standard that has been accepted by the Society. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

Section 2 FABRICATION BY WELDING

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the preparation, execution and inspection of welded connections in hull structures.

1.2 Limits of application to welding procedures

1.2.1 Weld type, size and materials

The requirements of this section for weld type, size and materials are based on the following considerations:

- Joint type.
- Criticality of the joint.
- Magnitude, type and direction of the stresses in the joint.
- Material properties of the parent and weld material.
- Weld gap size.

1.2.2 Preparation, execution and inspection

The requirements of this section are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society when deemed appropriate by the Society.

ISC 1.2.2a Welding procedures are also to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of ISC Rules for Materials and Welding.

2 WELDING PROCEDURES, WELDING CONSUMABLES AND WELDERS

2.1 General

2.1.1

All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables, in compliance with the Rules of the Society. Personnel manning automatic welding machines and equipment are to be competent, sufficiently trained and certified by the Society as specified in Society Rules or Guidelines for welding.

ISC 2.1.1a The approval of welding consumables, welding procedures and qualification tests of welders are to comply with the requirements of Chapters 2,3 and 4 of PART THREE of ISC Rules for Materials and Welding.
ISC 2.1.1b The qualification tests of automatic submerged arc welding operators are to comply with the requirements of Section 3, Chapter 3 of ISC Guidelines for Inspection of Hull Welds.

3 WELD JOINTS

3.1 General

3.1.1

Welding of connections is to be executed according to the approved plans.

3.1.2

The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case-by-case basis.

ISC 3.1.2a The quality standard adopted by the shipyard is to be in accordance with paragraph 1.2.1, Section 1 of this Chapter. In special cases, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

3.1.3

Consideration is to be given to the assembly sequence and the effect of the overall shrinkage of plate panels, assemblies, etc, resulting from the welding processes employed. Welding is to

proceed systematically, with each welded joint being completed in correct sequence, without undue interruption. When practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

3.1.4
Completed welded joints are to be to the satisfaction of the attending surveyor. Edge preparations and root gaps are to be in accordance with the approved welding procedure. The gap between the members being joined should not exceed the maximum values given in IACS Recommendation No. 47 or as specified in recognised fabrication standard approved by the Society. Where the gap between members being joined exceeds the specified values, corrective measures are to be taken in accordance with an approved welding procedure specification.

3.1.5
Where small fillets are used to attach heavy plates or sections, welding is to be based on approved welding procedure specifications. Special precautions, such as the use of preheating, low-hydrogen electrodes or low- hydrogen welding processes, are accepted.

3.1.6
When heavy structural members are attached to relatively light plating, the weld size and sequence may require modification.

3.1.7
Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than the minimum specified in Ch 12, Sec 3, [2.5.2] and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

3.1.8
In general, butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

3.1.9 Arrangements at junctions of welds
Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions can not be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of the size, and in a position, that a satisfactory return weld can be made.

3.1.10 Leak stoppers
Where structural members pass through the boundary of a tank, leakage into adjacent space could be hazardous or undesirable, and full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in a member close to the boundary outside of the compartment, and carefully welded all around.

4 NON-DESTRUCTIVE EXAMINATION (NDE)

4.1 General

4.1.1
The NDE plan to be submitted for approval has to contain the necessary data relevant to the locations and number of examinations, welding procedures applied, method of NDE applied, etc. Visual inspection of finished welds is to be carried out by the shipyard to ensure that all welding

has been satisfactory completed. In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld. Above inspections are to be carried out as per the requirements of the Society.

ISC 4.1.1a NDE is to be carried out in accordance with the applicable requirements of Section 3, Chapter 5,PART THREE of ISC Rules for Materials and Welding.

4.1.2

NDE of welding is to be carried out at the positions indicated by the NDE plan in order to ensure that the welds are free from cracks and unacceptable internal defects with regards to the requirements of the Society. NDE is to be carried out by qualified personnel certified by recognised bodies in compliance with recognised standards.

ISC 4.1.2a The acceptance standards of NDE of welds are to comply with the applicable requirements of Chapter 7 of ISC Guidelines for Inspection of Hull Welds.

Section 3 DESIGN OF WELD JOINTS

SYMBOLS

A_{weld} : Effective fillet weld area, in cm^2.
f : Root face, in mm.
f_{weld} : Weld factor.
f_{yd} : Correction factor taking into account the yield strength of the weld deposit as defined in [2.5.2].
l_{dep} : Total length of deposit of weld metal, in mm.
l_{leg} : Leg length of continuous, lapped or intermittent fillet weld, in mm.
l_{weld} : Length of the welded connection in mm.
R_{eH_weld} : Minimum yield stress of weld deposit, in N/mm^2.
$t_{as\text{-}built}$: As-built thickness of the member being joined, in mm.
t_{gap} : Allowance for fillet weld gap, is to be taken equal to 2.0 mm.
t_{throat} : Throat thickness of fillet weld in mm, as defined in [2.5.3].

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the design of welded connections in hull structures and are based on the considerations mentioned in Ch 12, Sec 2, [1.2.1].

1.1.2

Plans and/or specifications showing weld sizes and weld details are to be submitted for approval.

1.1.3

The leg length of welds is to comply with the minimum leg length given in Table 1.

1.2 Alternatives

1.2.1

The requirements given in this section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

ISC 1.2.1a The requirements given in this Section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details are to be approved in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

2 TEE OR CROSS JOINT

2.1 Application

2.1.1

The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown on Figure 1.

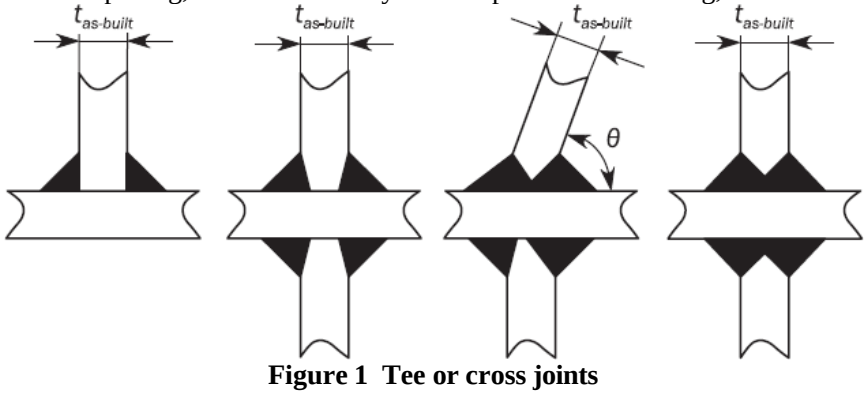


Figure 1 Tee or cross joints

$t_{as\text{-}built}$: As-built thickness of the member being attached, mm.

θ : Connecting angle, in deg.

2.1.2
Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate.

2.2 Continuous fillet welds

2.2.1
Continuous welding is to be adopted in the following locations:

a) Connection of the web to the face plate for all members.
b) All fillet welds where higher strength steel is used.
c) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
d) Boundaries of tanks and watertight compartments.
e) All structures inside tanks and cargo holds.
f) Stiffeners and primary supporting members at tank boundaries.
g) All structures in the aft peak and stiffeners and primary supporting members of the aft peak bulkhead.
h) All structures in the fore peak.
i) Welding in way of all end connections of stiffeners and primary supporting members, including end brackets, lugs, scallops, and at orthogonal connections with other members.
j) All lap welds in the main hull.
k) Primary supporting members and stiffener members to bottom shell in the 0.3 L forward region.
l) Flat bar longitudinals to plating.
m) The attachment of minor fittings to higher strength steel plating and other connections or attachments.
n) Pillars to heads and heels.
o) Hatch coaming stay webs to deck plating, see [2.4.5].

2.3 Intermittent fillet welds

2.3.1
Where continuous welding is not required, intermittent welding may be applied.

2.3.2
Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.
Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span at each end, in accordance with [2.5.2] and [2.5.3].

2.3.3 Deckhouses
One side continuous fillet welding is acceptable in the dry spaces of deckhouses.

2.3.4 Size for one side continuous weld
The size for one side continuous weld is to be of fillet required by [2.5.2] for intermittent welding, where f_3 factor is to be taken as 2.0.

2.4 Partial or full penetration welds

2.4.1 High stress area definition
For the application of this section, high stress area means an area where fine mesh finite element analysis is to be carried out and the fine mesh yield utilisation factor in elements adjacent to the weld is more than 90% of the fine mesh permissible utilisation factor, as defined in Ch 7, Sec 3, [6.2].

2.4.2 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical, full or partial penetration welds are to be used. In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

For partial penetration welds the root face, *f*, is, to be taken between 3 mm and $t_{as\text{-}built}/3$.

The groove angle made to ensure welding bead penetrating up to the root of the groove, α, is usually from 40°to 60°.

The welding bead of the full/partial penetration welds is to cover root of the groove. Examples of partial penetration welds are given on Figure 2.

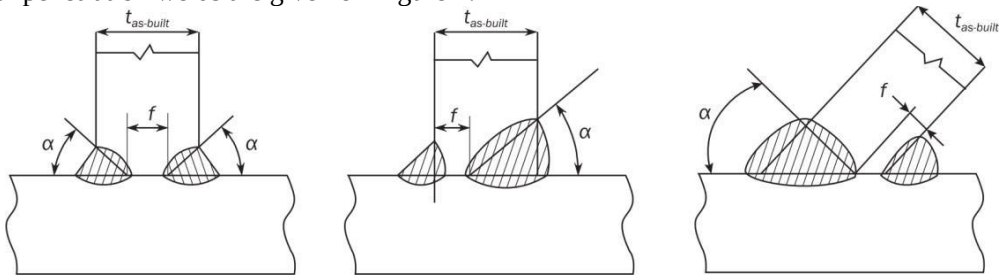


Figure 2 Partial penetration welds

2.4.3 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel is to satisfy the requirements given in [2.5.2].

2.4.4 Extent of full or partial penetration welding

The extent of full or partial penetration welding in each particular location listed in [2.4.5] and [2.4.6] is to be approved by the Society. However, the minimum extent of full/partial penetration welding from the reference point (i.e. intersection point of structural members, end of bracket toe, etc.) is not to be taken less than 300 mm, unless otherwise specifically stated.

2.4.5 Locations required for full penetration welding

Full penetration welds are to be used in the following locations and elsewhere as required by the rules, see Figure 3:

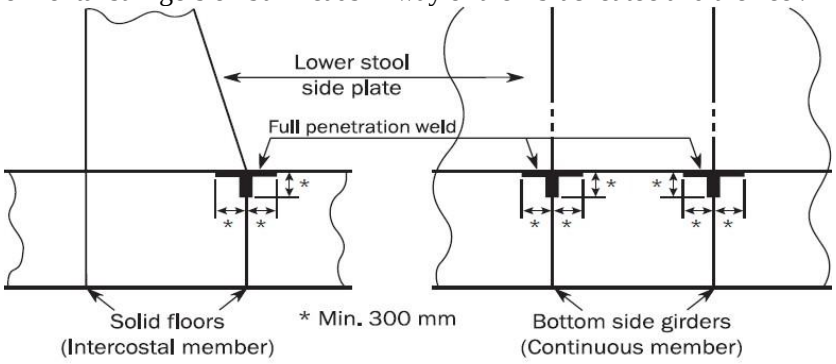
a) Floors to hopper/inner bottom plating in way of radiused hopper knuckle.
b) Radiused hatch coaming plate at corners to deck.
c) Connection of vertical corrugated bulkhead to the lower hopper plate and to the inner bottom plate within the cargo hold region, when the vertical corrugated bulkhead is arranged without a lower stool.
d) Connection of structural elements in the double bottom in line with corrugated bulkhead flanges to the inner bottom plate, when the vertical corrugated bulkhead is arranged without a lower stool.
e) Connection of vertical corrugated bulkhead to the lower hopper plate, and connection of structural elements in the lower hopper area in line with corrugated bulkhead flanges to the lower hopper plate, where connections are clear of lower stools.
f) Connection of vertical corrugated bulkhead to top plating of lower stool.
g) Corrugated bulkhead lower stool side plating to lower stool top plate.
h) Corrugated bulkhead lower stool side plating to inner bottom.
i) Connection of structural elements in double bottom to the inner bottom plate in holds intended for the carriage of liquid at sea with a distance of 150300 mm from the side plating of the lower stool, see Figure3.
j) Edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0.6 *L* amidships, when the dimensions of the opening exceeds 300 mm.
k) Abutting plate panels with as-built thickness less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, including but not limited to: sea chests, rudder trunks, and portions of transom. For as-built thickness greater than 12mm, partial penetration in accordance with [2.4.2].
l) Crane pedestals and associated bracketing and support structure.

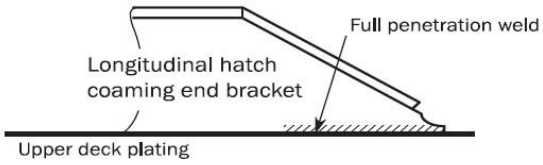
m) For toe connections of longitudinal hatch coaming end bracket to the deck plating, full penetration weld for a distance of 0.15 H_c from toe of side coaming termination bracket is required, where H_c is the hatch coaming height.
n) Rudder horns and shaft brackets to shell structure.
o) Thick flanges of long transverse web frames to side web frames. Thick flanges of long longitudinal girder to bulkhead web frames.

2.4.6 Locations required for partial penetration welding

Partial penetration welding as defined in [2.4.2], is to be used in the following locations (see examples in Figure
3):

a) Connection of hopper sloping plate to longitudinal bulkhead (inner hull) or horizontal girder in double side space.
b) End connection of longitudinal/transverse bulkhead primary supporting member including buttress structure to the double bottom and both end connections of backing bracket, where it is fitted.
c) Corrugated bulkhead lower stool supporting floors to inner bottom.
d) Corrugated bulkhead gusset and shedder plates.
e) Lower 15% of the length of built-up corrugation of vertical corrugated bulkheads
f) Structural elements in double bottom below bulkhead primary supporting members and stool plates, except in way of [2.4.5] i).
g) Lower hopper plate to inner bottom.
h) Horizontal stringers on bulkheads in way of their bracket toe and the heel.





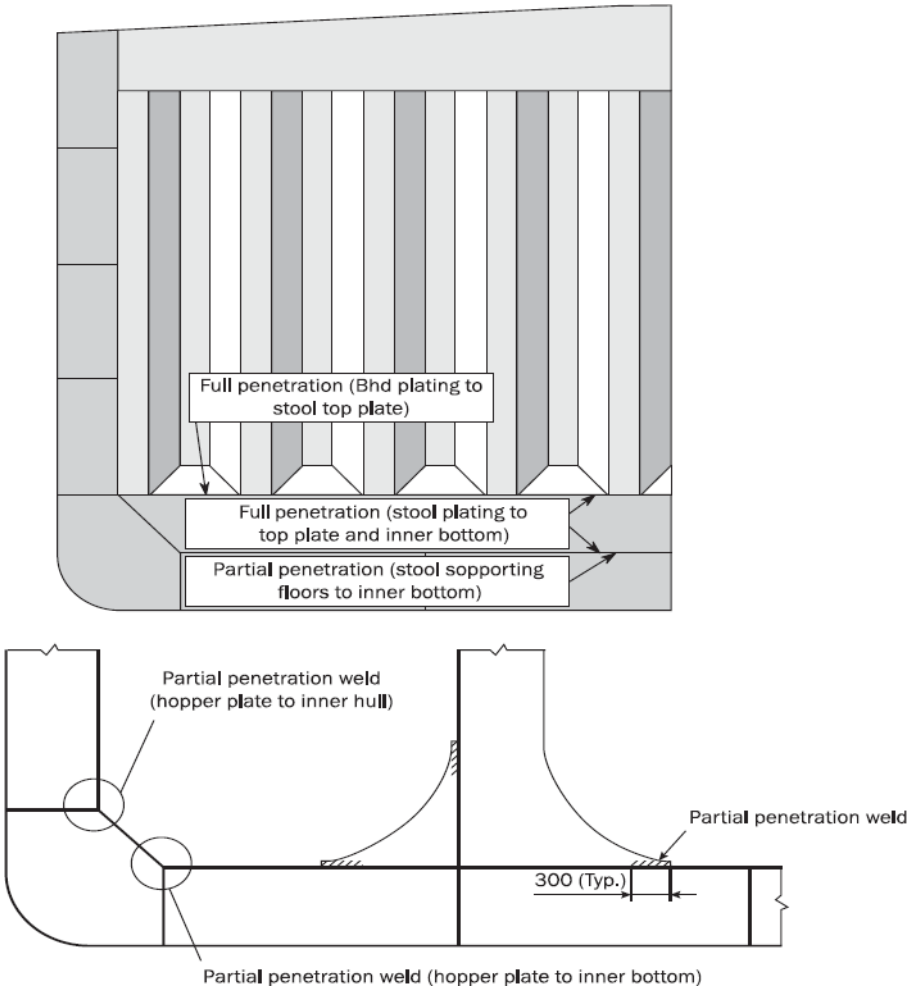


Figure 3 High stress areas welding (examples)

2.4.7 Fine mesh finite element analysis

In high stress area, at least partial penetration welds as defined in [2.4.2] are to be used. The minimum extent of full or partial penetration welding in that case is to be the greater of the following:

- 150 mm in either direction from the element with the highest yield utilisation factor.
- The extent covering all elements that exceed the above mentioned yield utilisation factor criteria.

2.4.8 Shedder plates

In case where shedder plates are fitted at the lower end of corrugated bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the transverse lower stool by one side penetration welds.

2.5 Weld size criteria

2.5.1

The required weld sizes are to be rounded to the nearest half millimetre.

2.5.2

The leg length, *lleg* in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

$l_{leg} = f_1 f_2 t_{as\text{-}built}$

$l_{leg} = f_{yd} f_{weld} f_1 f_2 t_{as\text{-}built} + t_{gap}$

l_{leg} as given in Table 1

where

f_1: Coefficient depending on welding type:

f_1 = 0.30 for double continuous welding.
f_1= 0.38 for intermittent welding.

f_2 : Coefficient depending on the edge preparation:
f_2 = 1.0 for welds without bevelling.
f_2 = 0.70 for welds with one/both side bevelling and $f = t_{as\text{-}built}$ /3.

f_{yd}: Coefficient not to be taken less than the following:

$$f_{yd} = (\frac{1}{k})^{0.5} (\frac{235}{R_{eH_weld}})^{0.75}$$

$f_{yd} = 0.71.$

R_{eH_weld} : Specified minimum yield stress for the weld deposit in N/mm^2, not to be less than:
: R_{eH_weld} = 305 N/mm^2 for welding of normal strength steel with R_{eH} = 235N/mm^2.
: R_{eH_weld} = 375 N/mm^2 for welding of higher strength steels with R_{eH} from 265 to 355 N/mm^2.
: R_{eH_weld} = 400 N/mm^2 for welding of higher strength steel with R_{eH} = 390N/mm^2.

f_{weld} : Weld factor dependent on the type of the structural member, see Table 2, Table 3 and Table 4.

k : Material factor of the abutting member.

f_3 : Correction factor for the type of weld:
f_3=1.0 for double continuous weld.
$f_3 = s_{ctr}/l_{weld}$ for intermittent or chain welding.

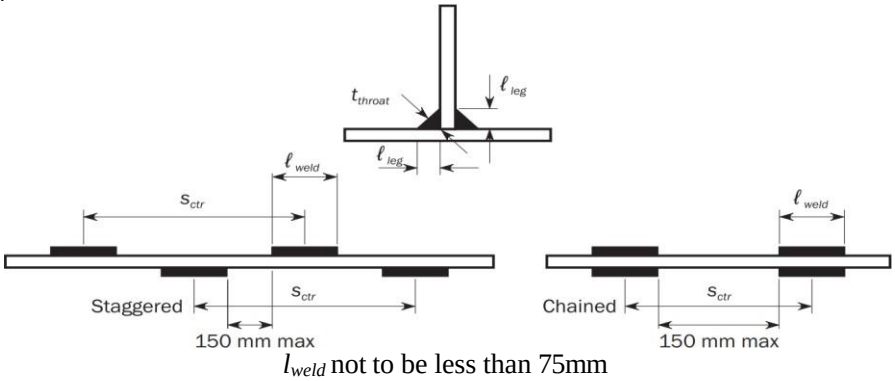
s_{ctr} : Distance between successive fillet welds, in mm.

Leg length for intermittent welding is not to exceed the greater of 6.5mm or 0.62 * $t_{as\text{-}built}$.

2.5.3

The throat size t_{throat}, in mm, as shown in Figure 4, is not to be less than:

$$t_{throat} = \frac{l_{leg}}{\sqrt{2}}$$



l_{weld} not to be less than 75mm

Figure 4 Weld scantlings definitions

2.5.4

For primary supporting members connections not listed in Table 2, and Table 3 the weld factors from Table 4 are to be used.

Minimum leg size **Table 1**

Area	Type of space		Minimum length, in mm
Cargo hold region	Cargo tanks and holds	Within 3m below top of tank(2)	6.5 (1)
		Elsewhere	6.0 (1)
	Water ballast tanks	Within 3m below top of tank(2)	6.5 (1)
		Elsewhere	6.0 (1)

Area	Type of space		Minimum length, in mm
	Dry spaces and voids		5.0
	Other tanks		6.0 (1)
Other areas	Water ballast tanks	Within 3m below top of tank(2)	6.0 (1)
		Elsewhere	5.5 (1)
	Fuel oil, diesel oil , fresh water and other tanks		4.5
	Dry spaces and voids		4.0
	Superstructures and deckhouses		3.5

(1) If the as-built thickness of the element is less than 12 mm, the minimum leg length may be reduced by 0.5 mm.

(2) Only applicable to cargo tanks and ballast tanks with weather deck as the tank top. The 3m distance is measured vertically from and parallel to the top of the tank.

Weld factors for different structural members **Table 2**

Hull area	Connection				f_{weld}
	Of		To		
General, unless otherwise specified in the table	Watertight plate		Boundary plating		0.48
	Oil-tight plate		Boundary plating		0.51
	Brackets at ends of members				0.48
	Ordinary stiffener and collar plates		Deep tank bulkheads		0.24
			Web of primary supporting members and collar plates		0.38
	Web of stiffener		Plating (except deep tank bulkhead)		0.20
			Face plates of built-up stiffeners	At ends (15% of span)	0.38
				Elsewhere	0.20
Bottom and double bottom	Ordinary stiffener		Bottom and inner bottom plating		0.24
	Centre girder		Shell plates		0.38
			Inner bottom plate		0.38
	Side girder including intercostal plates		Bottom and inner bottom plating		0.24
	Floor		Shell plates and inner bottom plates	At ends, on a length equal to two frame spaces	0.38
			Centre girder and side girders in way of hopper tanks		0.38
			Elsewhere		0.24
	Bracket on centre girder		Centre girder, inner bottom, floors and shell plates		0.38
	Web stiffener		Floor and girder		0.20
Side and inner side in double side structure	Web of primary supporting members		Side plating		0.30
			Inner side plating and web of primary supporting members	in way of deck transverse and end connections	0.43
				in way of cross tie	0.36
				elsewhere	0.30
Deck	Strength deck	$t_{as_built} \geqslant 13$	Side shell plating within 0.6L midship		PPW [3]
			Elsewhere		0.48
		$t_{as_built} < 13$	Side shell plating		0.48
	Other deck		Side shell plating		0.38
			Stiffeners		0.20
	Hatch coamings		Deck plating	Longitudinal hatch coaming at corners of hatchways on a length of 15% of the hatch coaming height	FPW [4] [1]
				Longitudinal hatch coaming on a length starting from 15% of the hatch coaming height from the corners of hatchways up to 15% of the hatch length	0.48
				Elsewhere	0.38
	Web stiffeners		Coaming webs		0.20 [2]
Bulkheads [5]	Non-watertight bulkhead structure		Boundaries	Swash bulkheads	0.24
	Stiffener		Bulkhead plating	At ends (25% of span), where no end brackets are fitted	0.48

Hull area	Connection		f_{weld}
	Of	To	
Aft peak	Internal members	Boundaries and each other: below waterline	0.38
		Above waterline	0.20
Fore peak	Internal members	Boundaries and each other	0.20
Machinery space	Centre girder	Keel and inner bottom	0.48
	Floor	Centre girder and engine foundation girder	0.48
	Engine foundation girders	Top plate of main engine bed and inner bottom plate, where applicable	PPW (3)
	Floors and girders	Inner bottom and shell plate	0.38
Superstructure and deckhouse	External bulkhead (first and second tier erections)	Deck, external bulkhead	0.48
	External bulkheads and internal bulkheads	Elsewhere	0.20

(1) f_{weld} =0.43 for hatch coaming other than in cargo holds.
(2) Continuous welding.
(3) PPW: Partial penetration welding in accordance with [2.4.2]. When one side partial penetration weld is adopted, f_{weld} = 0.48 is to be used for the fillet.
(4) FPW: Full penetration welding in accordance with [2.4.2].
(5) Bulkheads of superstructure and deckhouse are to be considered in the row corresponding to "Superstructure and deckhouse".

Weld factors for miscellaneous fittings and equipment **Table 3**

Item		Connection to	f_{weld}
Hatch cover	Primary supporting members	At ends (10% of span) of PSM	0.48(1)
		Elsewhere	0.24
	Stiffeners	At ends	0.38 (2)
		Elsewhere	0.20
Mast, derrick post, crane pedestal, etc.		Deck / Underdeck reinforced structure	0.43
Deck machinery seat		Deck	0.24
Mooring equipment seat		Deck	0.43
Ring for access hole type cover		Anywhere	0.43
Stiffening of side shell doors and weathertight doors		Anywhere	0.24
Frames of shell and weathertight doors		Anywhere	0.43
Coaming of ventilator and air pipe		Deck	0.43
Ventilators, etc., fittings		Anywhere	0.24
Scupper and discharge		Deck	0.55
Bulwark stay		Deck	0.24
Bulwark plating		Deck	0.43
Guard rail, stanchion		Deck	0.43
Cleats and fittings		Hatch coaming and hatch cover	0.24 (3)

(1) For bulk carrier hatch covers f_{weld} = 0.38.
(2) For bulk carrier hatch covers f_{weld} = 0.24 at ends of stiffeners.
(3) Minimum weld factor. Where $t_{as\text{-}built}$>11.5mm l_{leg} need not exceed 0.62$t_{as\text{-}built}$. Penetration welding may be required depending on design.

Weld factors for primary supporting members **Table4**

Hull structural member	Connection			f_{weld}
	Of	To		
Primary supporting member	Web plate	Shell plating, deck plating, inner bottom plating, bulkhead	Within end 15% of shear span and extending to end of member	0.48
			Elsewhere	0.38
		Face plate	In tanks/holds Members located within 0.125L from fore peak	0.38
			Elsewhere if cross section area of face plate exceeds 65 cm^2	0.38
			Elsewhere	0.24
	End connections		In way of boundaries of ballast and cargo tanks	0.48
			Elsewhere	0.38

2.5.5

Where the as-built web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the attached plating, the welding is to be double continuous and the leg length of the weld is not to be less than the largest of the following:

a) $0.30t_{as\text{-}built}$, where $t_{as\text{-}built}$ is the as-built thickness of the attached plating without being taken greater than 30 mm.

b) $0.27t_{as\text{-}built} + 1$, where $t_{as\text{-}built}$ is the as-built thickness of the abutting member. The leg size resulting of this formula needs not to be taken greater than 8.0 mm.

c) Leg length given in the Table 1.

2.5.6

Where the minimum weld size is determined by the requirements of second formula shown in [2.5.2], the weld connections to shell, decks or bulkheads are to take account of the material lost in the cut out, where stiffeners pass through the member. In cases where the width of the cut-out exceeds 15 % of the stiffener spacing, the size of weld leg length is to be multiplied by:

$$\frac{0.85s}{l_w}$$

where:

s : Stiffener spacing in mm, as shown in Figure 5.

l_w : Length of web plating between notches, in mm, as shown in Figure 5.

2.5.7 Shear area of primary supporting member end connections

Welding of the end connections, inclusive 10% of shear span, of primary supporting members is to be such that the weld area is to be equivalent to the gross cross sectional area of the member. The weld leg length in mm, l_{leg}, is to be taken as:

$$l_{leg} = 1.41 f_{yd} \frac{h_w t_{gr-req}}{l_{weld}}$$

where:

h_w : Web height of primary supporting members, in mm.

t_{gr_req} : Required gross thickness of the web in way of the end connection, including 10% of shear span, based on the highest average usage factor for yield from cargo hold FE analysis or the shear area requirement for PSM outside cargo hold region, in mm.

l_{weld} : Length of the welded connection in mm, as shown in Figure 6.

l_{dep} : Total length of deposit of weld metal, in mm, see Figure 6 taken as:
$l_{dep} = 2\ l_{weld}$

The size of weld is not to be less than the value calculated in accordance with [2.5.2].

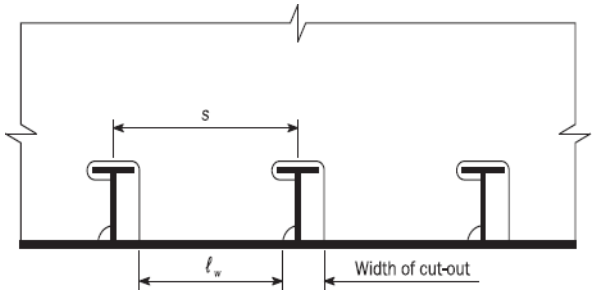


Figure 5 Effective material in web cut-outs for stiffeners

2.5.8 Longitudinals

Welding of longitudinals to plating is to be doubled continuous at the ends of the longitudinals at the extent of 15 % of shear span as defined in Ch 3, Sec 7, [1.1.3].

In way of primary supporting members, the length of the double continuous weld is to be equal to the depth of the longitudinal or the end bracket, whichever is greater.

2.5.9 Deck longitudinals

For deck longitudinals, a matched pair of welds is required at the intersection of longitudinals with primary supporting members.

2.5.10 Longitudinal continuity provided by brackets

Where a longitudinal strength member is to cut at a primary supporting structure and the continuity of strength is provided by brackets, the weld area A_{weld} is not to be less than the gross cross sectional area of the member. The weld area, A_{weld} in cm^2, is to be determined by the following formula:

$$A_{weld} = \frac{f_{yd} t_{throat} l_{dep}}{100}$$

2.5.11 Unbracketed stiffeners

Where intermittent welding is permitted, unbracketed stiffeners of shell, watertight and oil-tight bulkheads, and deckhouse fronts are to have double continuous welds for one-tenth of their length at each end. Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and aft ends are to have a pair of matched intermittent welds at each end.

2.5.12 Reduced weld size

Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1 mm and less, the weld factors given in Table 2 may be reduced by 15% but not more than fillet weld leg size of 1.5 mm. Reductions of up to 20%, but not more than the fillet weld leg size of 1.5 mm, will be accepted provided that the shipyard is able to consistently meet the following requirements:

a) The welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.
b) The penetration at the root is at least the same amount as the reduction into the members being attached.
c) Demonstrate that an established quality control system is in place.

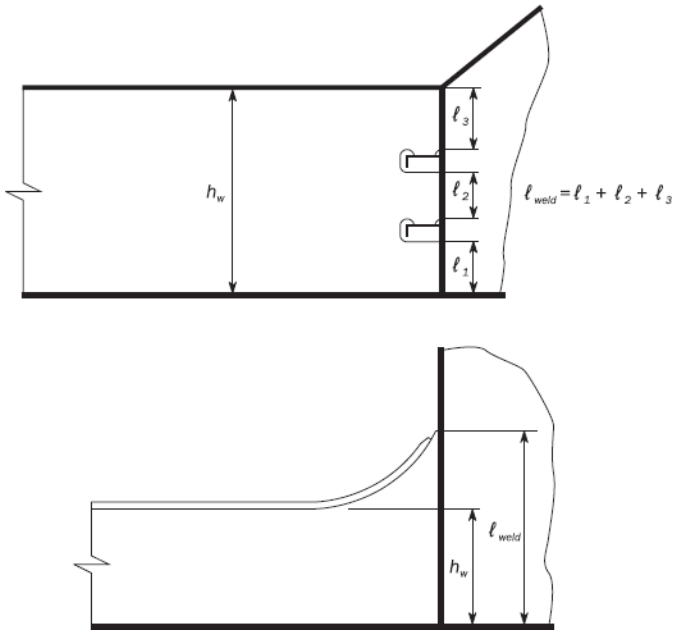


Figure 6 Shear area of primary supporting member

Note1: The length l_{weld} is the length of the welded connection. The total length of the weld deposit l_{dep} if welded with double continuous fillet welds is twice the length of the welded connection l_{weld}.

2.5.13 Reduced weld size justification

Where any of the methods for reduction of the weld size are adopted, the specific requirements giving justification for the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [2.5.2] without the leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

3 BUTT JOINT

3.1 General

3.1.1

Joints in the plate components of stiffened panel structures are generally to be joined by butt welds, see Figure 7.

3.2 Thickness difference

3.2.1 Taper

In the case of welding of plates with difference in as-built thickness greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as- built thickness. If the width of groove is not less than 3 times the difference the transition taper is to be avoided.

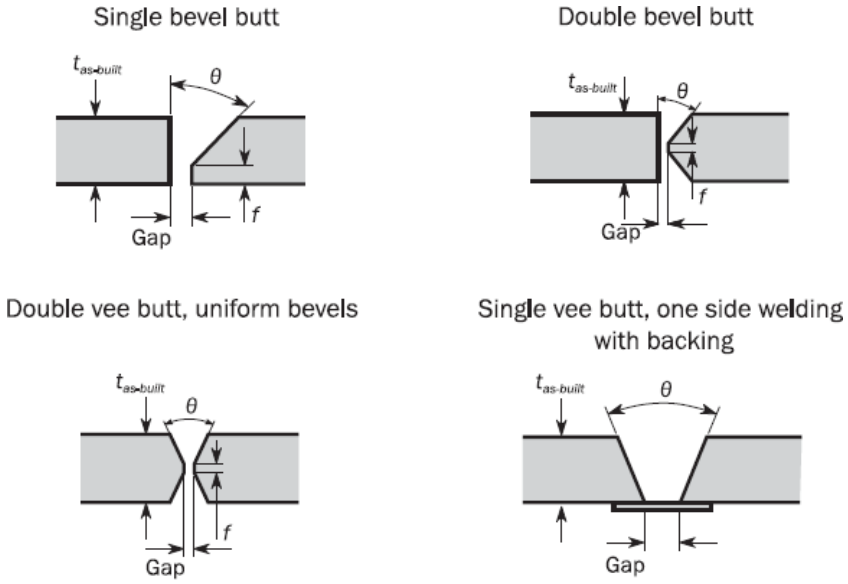


Figure 7 Typical butt welds

4 OTHER TYPES OF JOINTS

4.1 Lapped joints

4.1.1 Areas

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the following:

- Peripheral connections of doublers.
- Internal structural elements subject to very low stresses.

4.1.2 Overlap width

Where overlaps are adopted, the width of the overlap is not to be less than three times, but not greater than four times the as-built thickness of the plates being joined, see Figure 8. Where the as-built thickness of the thinner plate being joined has a thickness of 25 mm or more, the overlap will be subject to special consideration.

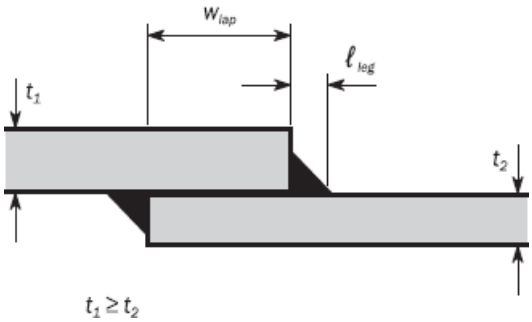


Figure 8 Fillet weld in lapped joint

4.1.3 Overlaps for lugs

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug but need not be greater than 50 mm.

4.1.4 Lapped end connections

Lapped end connections are to have continuous welds on each edge with leg length, l_{leg} in mm, as shown on Figure 8 such that the sum of the two leg lengths is not less than 1.5 times the as-built thickness of the thinner plate.

4.1.5 Overlapped seams

Overlapped seams are to have continuous welds on both edges, of the sizes required by [2.5.2] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of

12.5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [2.5.2] for watertight bulkhead boundaries.

4.2 Slot welds

4.2.1

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 L amidships.

ISC 4.2.1a Slot welds are not adopted in general. Where internal access for welding from the back side is not practicable, e.g. where direct application of fillet welding is not practicable for the connection of plating to internal webs, slot welds may be adopted. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 L amidships.

4.2.2

Slots are to be well-rounded and have a minimum slot length, l_{slot} of 75 mm and width, w_{slot} of twice the as- built plate thickness. Where used in the body of doublers and similar locations, such welds are in general to be spaced a distance, s_{slot} of $2l_{slo}$ to $3l_{slo}$ but not greater than 250 mm, see Figure 9. The size of the fillet welds is to be determined from second formula shown in [2.5.2] using $t_{as\text{-}built}$ of the thinner plate and a weld factor of 0.48.

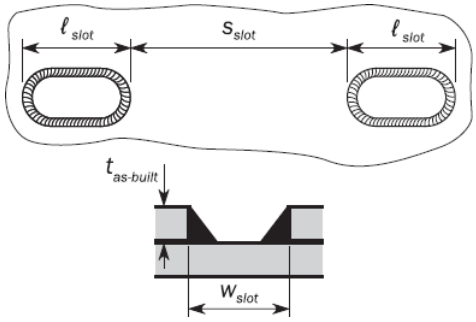


Figure 9 Slot welds

4.2.3 Closing plates

For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot welds to face plates fitted to the webs.

4.2.4

Slots are to be well-rounded and have a minimum slot length, l_{slot} of 90 mm and a minimum width, w_{slot} of twice the as-built plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance, s_{slot} not greater than 140 mm. Slots are not to be filled with welding.

4.3 Stud and lifting lug welds

4.3.1

Where permanent or temporary studs or lifting lugs are to be attached by welding to main structural parts in areas subject to high stress, the proposed locations are to be submitted for approval.

5 CONNECTION DETAILS

5.1 Bilge keels

5.1.1

The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Table 5.

Connections of bilge keels **Table 5**

Structural items being joined	Leg length of weld, in mm	
	At ends(1)	Elsewhere
Ground bar to the shell	0.62 t_{1as_built}	0.48 t_{1as_built}
Bilge keel web to ground bar	0.48 t_{2as_built}	0.30 t_{2as_built}

$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm.
$t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm.
(1): Zone "*b*" in Fig. 19 and Fig. 20 in Pt 1 Ch 3 Sec 6 for definition of "ends".

5.1.2
Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Figure 10. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

5.1.3
The ground bar is to be continuously fillet welded with a leg length as given in Table 4. At the ends of the ground bar, the leg length is to be increased as given in Table 4, without exceeding the as-built thickness of the ground bar as shown in Figure 10. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45 deg or less.

5.1.4
In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

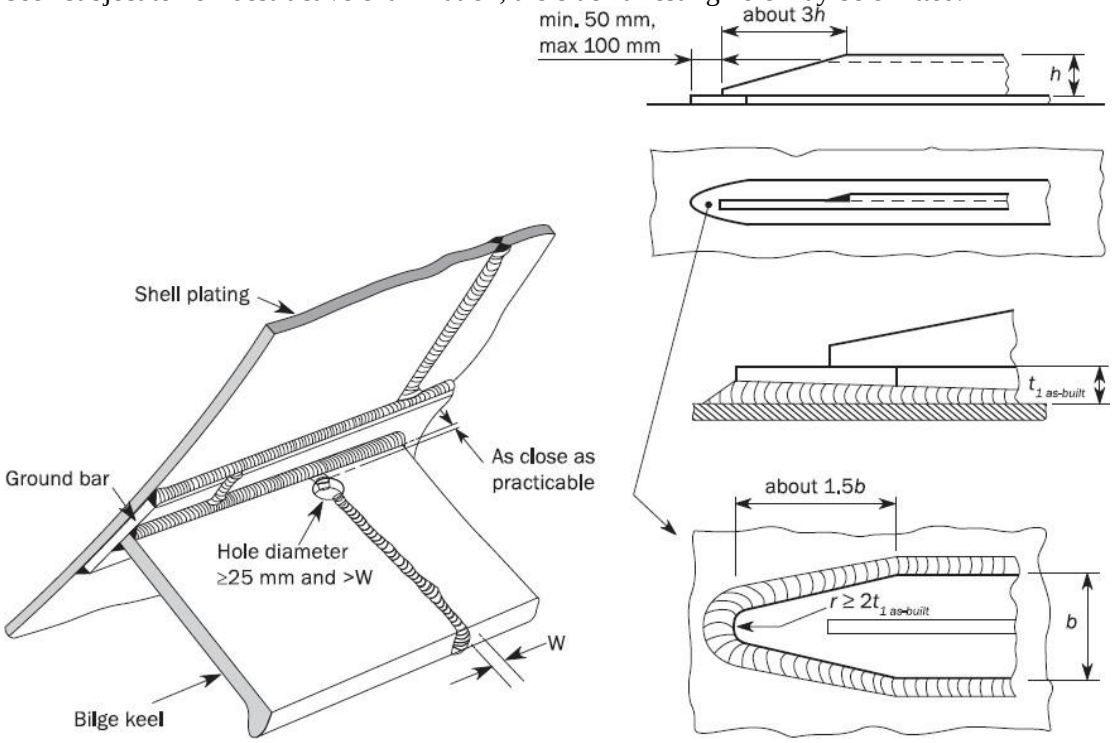


Figure 10 Bilge keel

5.2 Bulk carrier side frames
5.2.1

The following requirements are applicable to side frames, end brackets and tripping brackets of single side skin bulk carriers.

5.2.2

For zones 'a' and 'b' as shown in Figure 11, double continuous fillet welding should be used with leg lengths of $0.62t_{as\text{-}built}$ and $0.57t_{as\text{-}built}$ respectively where $t_{as\text{-}built}$ is the as-built thickness of the thinner of two connected members, in mm.

5.2.3

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating. The leg length, l_{leg} in mm, for these connections should be taken as:

- $0.5t_{as\text{-}built} + 1.0$ if $t_{as\text{-}built} < 10$
- $0.4\ t_{as\text{-}built} + 1.0$ if $10 \leqslant t_{as\text{-}built} < 20$
- $0.3\ t_{as\text{-}built} + 1.0$ if $t_{as\text{-}built} \geqslant 20$

In these formulas $t_{as\text{-}built}$ is as-built thickness of the abutting plate.

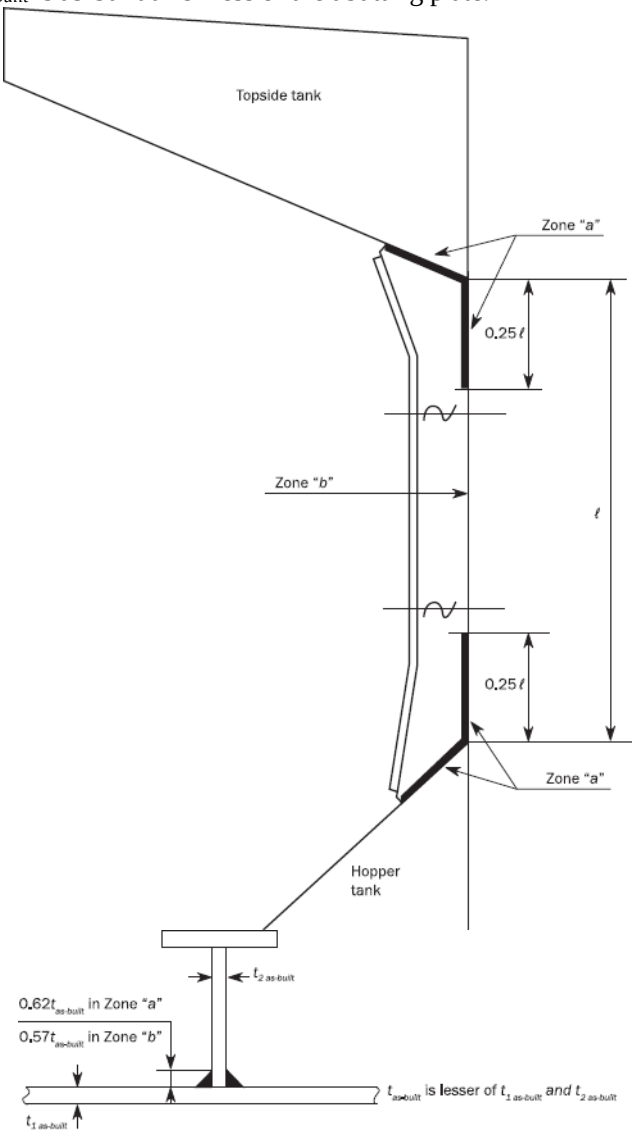


Figure 11 Bulk carrier side frames

5.3 End connections of pillars and cross ties

5.3.1

The end connections of pillars and cross ties are to have an effective fillet weld area, in cm^2, (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3(\frac{235}{R_{eH_weld}})^{0.75} F$$

where:

F : Design load, for the structure under consideration, in kN.
f_3 : Coefficient equal to:
f_3 = 0.05 when pillar or cross tie is in compression only.
f_3= 0.14 when pillar or cross tie is in tension.

5.4 Abutting plates with small angles

5.4.1

Where the angle θ between the abutting plate and the connected plate is less than 75 deg as shown in Figure 12, the size of fillet welds l_θ, in mm, for the side of larger angle is to be increased in accordance with:

$$l_\theta = \frac{l_{leg}}{\sqrt{2}\sin\frac{\theta}{2}}$$

where:

l_{leg} : Leg length of fillet weld, in mm, as defined in [2.5.2].
θ : Connecting angle, in deg, as shown in Figure 12.

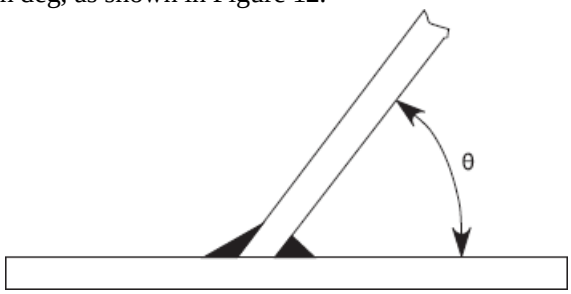


Figure 12 Connecting angle

5.4.2

Connections of main strength members where θ is less than 45 deg, see Figure 12, may be applied only in dry spaces and voids.

Chapter 13 SHIP IN OPERATION - RENEWAL CRITERIA

Section 1 PRINCIPLES AND SURVEY REQUIREMENTS

1 PRINCIPLES

1.1 Application

1.1.1

The purpose of this chapter is to provide criteria for the allowable thickness diminution of ships'hull structures.

1.1.2

The criteria apply only to ships in operation that are classed in accordance with these Rules.

1.1.3

Thickness measurement is to be used to assess ships' hull structures against the specified renewal criteria.

1.1.4

The hull survey requirements are those given, as applicable, in the Rules and/or documents of the individual Society which incorporate:

- UR Z10.2 for single side skin bulk carriers.
- UR Z10.4 for double hull oil tankers.
- UR Z10.5 for double side skin bulk carriers.

1.2 Corrosion allowance concept

1.2.1 Corrosion allowance

Corrosion allowance is comprised of two aspects: local and global corrosion, as defined in Ch 3, Sec 2, [1.1.2].

1.2.2 Assessment

Assessment against both local and global corrosion renewal criteria is required during the operational life of ships.

Assessment against the newbuilding requirements which incorporate corrosion additions, given in Ch 3, Sec 3, and which consider all relevant loads and limit states, e.g. yielding, buckling, and fatigue is not required during the operational life of ships, provided that the measured thickness of any structural members remain greater than the renewal thickness specified in Ch 13, Sec 2, [2].

1.2.3 Steel renewal

Steel renewal is required if either the local or global corrosion allowance is exceeded.

1.3 Requirements for documentation

1.3.1 Plans

The plans to be supplied onboard the ship, as required in Ch 1, Sec 3, are to include, for each structural element, both the as-built and renewal thickness as defined in Ch 13, Sec 2. Any thickness for voluntary addition is also to be clearly indicated on the plans.

For the list of plans and information to be supplied onboard the ship, reference is made to the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 or Z10.5 as applicable.

1.3.2 Hull girder sectional properties

The Midship section plan to be supplied onboard the ship is to include the minimum required hull girder sectional properties, as defined in Ch5, Sec 1, for the representative transverse sections of all cargo holds.

2 HULL SURVEY REQUIREMENTS

2.1 General

2.1.1 Minimum hull survey requirements

The minimum hull survey requirements including thickness measurements for the maintenance of class are given in the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5.

Section 2 ACCEPTANCE CRITERIA

SYMBOLS

$t_{as\text{-}built}$ *:* As built thickness, in mm.
t_c *:* Corrosion addition in mm, as defined in Ch 3, Sec 2.
t_{res} *:* Reserve thickness, taken equal to 0.5 mm.
t_{vol_add} *:* Thickness for voluntary addition, in mm.

1 GENERAL

1.1 Application

1.1.1

This section gives requirements for the application of the acceptance criteria.

1.2 Definition

1.2.1 Deck zone

The deck zone includes all the following items contributing to the hull girder strength:

- For bulk carriers: elements above or crossed by the 0.9 *D* level line above the baseline such as:
  - Strength deck plating.
  - Deck stringer.
  - Sheer strake.
  - Side shell plating.
  - Inner hull and other longitudinal bulkhead plating, if any.
  - Topside tank sloped plating, including horizontal and vertical strakes.
  - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.
- For oil tankers: elements above or crossed by the 0.9D level line above the baseline such as:
  - Strength deck plating.
  - Deck stringer.
  - Sheer strake.
  - Inner hull and other plane longitudinal bulkheads upper most strake.
  - Topside tank sloped plating, including horizontal and vertical strakes.
  - Longitudinal upper stool.
  - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.

1.2.2 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength:

- For bulk carriers: elements up to the upper level of the hopper sloping plating or up to and including the inner bottom plating if there is no hopper tank:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Bottom girders.
  - Inner bottom plating.
  - Hopper tank sloping plating, and horizontal plating, if any.
  - Side shell plating.
  - Plane longitudinal bulkheads lower strake.
  - Longitudinal stiffeners connected to the above mentioned plating.
- For oil tankers:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Plane longitudinal bulkheads lower strake.
  - Bottom girders.

- Inner bottom plating.
- Hopper tank sloping plating, and horizontal plating, if any.
- Side shell plating.
- Longitudinal lower stool.
- Longitudinal stiffeners connected to the above mentioned plating.

1.2.3 Neutral axis zone

The neutral axis zone includes the following items between the deck zone and the bottom zone, as for example:

- Side shell plating.
- Inner hull plating and longitudinal bulkheads, if any.
- Topside tank sloped plating.

For the longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the zone area is to be based on the projected area onto the vertical plane.

2 RENEWAL CRITERIA

2.1 Local corrosion

2.1.1 Renewal thickness of local structural elements

Local structural elements include local supporting members and primary supporting members.
Steel renewal is required if the measured thickness, *tm* in mm, is less than the renewal thickness, t_{ren} defined as:

$$t_{ren} = t_{as-built} - t_c - t_{vol_add}$$

2.1.2 Renewed area

Areas which need to be renewed based on the renewal criteria in [2.1.1] are, in general, to be repaired with inserted material which is to have the same or greater grade and yield stress as the original, and to have a thickness, t_{repair} in mm, not less than:

$$t_{repair} = t_{as-built} - t_{vol_add}$$

2.1.3 Alternative solutions

Alternative solutions may be adopted in accordance with the requirements of the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5, where the measured thickness, t_m is such as:

$$t_{ren} \leqslant t_m < t_{ren} + t_{res}$$

2.2 Global corrosion

2.2.1 Application

The ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during special surveys, for ships over 10 years of age.

2.2.2 Renewal criteria

The hull girder strength criteria are given as detailed below.

a) Deck and bottom zones:
The current hull girder section modulus at deck and at bottom determined with the thickness measurements are not to be less than 90% of the section modulus calculated according to Ch 5, Sec 1 with the gross offered thickness.
Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the measured item areas of the considered zones are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thickness.

b) Neutral axis zone:
The current sectional area of the neutral axis zone, which is the sum of the measured plating areas of this zone, is not to be less than the sectional area of the neutral axis zone calculated with the gross offered thickness minus 0.5 t_c.

If the actual reduction of the gross offered thickness of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and $0.5t_c$ for the neutral axis zone, the hull girder strength criteria of this transverse section is satisfied and the calculations of the different zone areas with measured thicknesses need not be carried out.
The gross offered thickness is defined in Ch 3, Sec 2.

ISC Appendix A WAVE LOAD DIRECT CALCULATION METHOD BASED ON EQUIVALENT DESIGN WAVE METHOD

Symbols:

t : *Time, in s.*

V : *Ship speed under consideration, in m/s.*

x,y,z : *Coordinate X, Y and Z of the considered point in reference coordinate system as defined in [1.2], in m.*

x_G,y_G,z_G :*Coordinate X, Y and Z of ship gravity center corresponding to the considered loading condition in reference coordinate system as defined in [1.2], in m.*

L : *Rule length, in m.*

ω_e: *Encounter frequency.*

η_i (i=1,6)*: Ship motions displacements relative to the ship gravity center in six degrees of freedom as surge, sway, heavy, roll, pitch and yaw.*

θ *: Roll amplitude, in rad.*

φ *: Pitch amplitude, in rad.*

a_X, a_Y, a_Z *: Acceleration of any point.*

f_S : *Coefficient for symbol. For vertical bending moment, hogging is positive and sagging is negative. For horizontal bending moment, tension on the starboard side is positive and compression on the starboard side is negative.*

f_{ps} *: Coefficient for strength assessments which is dependent on the applicable design load scenario specified in Section 7, Chapter 4 of PART 9-1 and to be taken as :*

f_{ps} *= 1.0 for extreme design load scenario and fatigue assessment.*

f_{ps} *= 0.9 for fatigue assessment.*

f_{ps} *= 0.8 for the ballast water exchange design load scenario.*

f_{ps} *= 0.8 for the accidental flooded design load scenario at sea.*

f_{ps} *= 0.4 for the harbour/sheltered water design load scenario.*

f_β *: Heading correction factor, to be taken as :*

- *For strength assessment*

  f_β *= 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.*

  f_β *=1.0 for HSM, HSA, FSM, OST and OSA load cases for the extreme sea loads design load scenario.*

  f_β *=1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.*

- *For fatigue assessment*

  f_β *=1.0.*

f_m : *Distribution factor for vertical wave bending moment along the ship's length, see Figure 3-1.*

f_{nl} : *Coefficient considering nonlinear effects applied to vertical wave bending moment. For strength assessment, in hogging condition, it is taken as $f_{nl\text{-}vh}$; in sagging condition, it is taken as $f_{nl\text{-}vs}$. For fatigue assessment, f_{nl} is taken as 1.0.*

$f_{nl\text{-}vh}$ *: Taken as* $\dfrac{0.19C_B}{0.15C_B+0.0385}$

$f_{nl\text{-}vs}$*: Taken as* $\dfrac{0.11C_B+0.077}{0.15C_B+0.0385}$

M_{WV} *: Vertical wave bending moment in given loading and given equivalent design wave, in kNm.*

Q_{WV} *: Vertical wave shear force in given loading and given equivalent design wave, in kN.*

M_{WH} *: Horizontal wave bending moment in given loading and given equivalent design wave, in kNm.*

M_{WT} *: Wave torsional moment in given loading and given equivalent design wave, in kNm.*

P_{ex} *: Total sea pressure in given loading and given equivalent design wave, in kN/m^2.*

P_{es} *: Hydrostatic pressure in given loading and given equivalent design wave, in kN/m^2.*

P_{ed} *: Hydrodynamic pressure in given loading and given equivalent design wave, in kN/m^2.*

P_{in} *: Total internal pressure in given loading and given equivalent design wave, in kN/m^2.*

1 GENERAL PROVISIONS

1.1 Application

This Appendix is applicable to the wave load direct calculation of oil tankers and bulk carriers with unrestricted worldwide navigation and may also be used as a reference for the wave load direct calculation of oil tankers and bulk carriers of other service areas.

1.2 Reference coordinate system

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system (see Figure 1-1) :

Origin : at the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline;

X axis : longitudinal axis, positive forwards;

Y axis : transverse axis, positive towards portside;

Z axis : vertical axis, positive upwards.

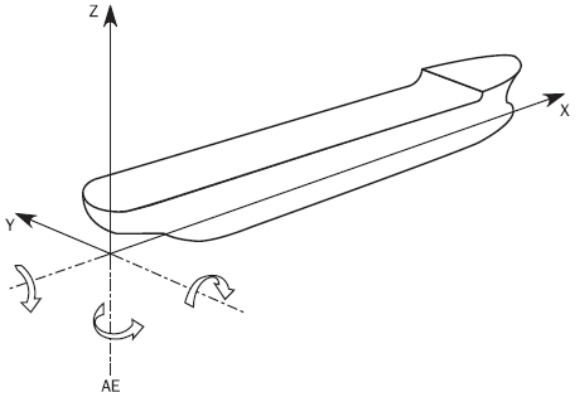


Figure 1-1 Reference Coordinate System

2 PRINCIPLE OF EQUIVALENT DESIGN WAVE METHOD

2.1 Wave load direct calculation method

Wave load direct calculation method is based on the three-dimensional linear potential flow theory. Once the fluid velocity potential at the junction of fluid and hull together with its partial derivative in relation to the space coordinate are obtained, the interacting forces between fluid and hull can be obtained, then hull motion responses and section loads will be obtained, based on the Bernoulli's equation.

The solution for velocity potential is mainly to solve a boundary integral equation for meeting definite conditions, i.e. the fluid domain condition, the free surface condition, the body surface condition, the bottom condition and the remote radiation condition. Current solving methods mainly include free surface Green function method in frequency domain or time domain and the simple Green function method.

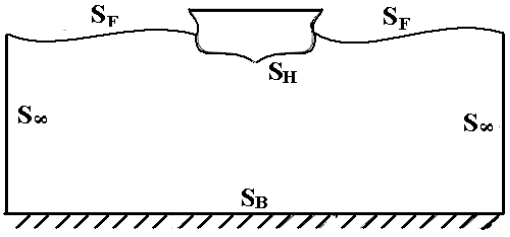


Figure 2-1 Boundary Condition for the Solution of Velocity Potential

Based on the Bernoulli's equation, the diffraction pressure response function and hydrodynamic coefficient will be obtained and then the ship's motions, accelerations and radiation pressure response function together with the response function of section loads will be obtained when the velocity potential is obtained.

2.2 Long term and short term prediction of linear wave loads

2.2.1 Short term prediction of linear wave loads

The short-term wave may be regarded as stationary random Gaussian process with average value of zero. Based on the random process theory, the response wave loads (output) subject to the wave

(input) will also be stationary random Gaussian process with average value of zero. The relationship between input wave spectrum S_ζ and output response spectrum S_w is expressed by the following formula:

$$S_W(\omega, H_{1/3}, T_Z, V, \beta+\theta) = H^2(\omega, V, \beta+\theta) S_\zeta(\omega, H_{1/3}, T_Z, \theta)$$

where:

ω is wave frequency, $H_{1/3}$ is significant wave height, T_Z is average zero-crossing period, V is ship speed, β is course and θ is heading angle.

For a stationary random Gaussian process with average value of zero, under the narrow spectrum assumption, the amplitude complies with Rayleigh distribution and the corresponding probability density is:

$$f_0(x) = \frac{2x}{E[(H_{1/3}, T_Z), V, \beta]} \exp[-\frac{x^2}{E[H_{1/3}, T_Z], V, \beta}]$$

where:

E is two times wave load variance, expressed as follows:

$$E[(H_{1/3}, T_Z), V, \beta] = 2\int_{-\pi/2}^{+\pi/2}\int_0^\infty S_W(\omega, H_{1/3}, T_Z, V, \beta+\theta)\,\mathrm{d}\omega\,\mathrm{d}\theta$$

The distribution function, 1/3 significant value and 1/10 significant value of loads are obtained in accordance with load response function and wave parameters.

2.2.2 Long term prediction of linear wave loads

Where it is assumed that short term conditions consisting of various different sea states and navigation conditions are independent from each other, the long term probability distribution will be the weighted combination of short term probability distribution, i.e. the exceedance probability of the wave load amplitude X greater than certain fixed value x is :

$$Q(x) = p\{X \geq x\} = \sum_i \sum_j \sum_k p_i(H_{1/3}, T_Z), p_i(H_{1/3}, T_Z), p_j(\beta), p_k(V) \exp\left\{\frac{-x^2}{E[(H_{1/3}, T_Z]_i, \beta_j, V_K}\right\}$$

The probability of occurrence of heading angle is assumed to be uniformly distributed between 0 and 2π. The probability of occurrence of sea state depends on the wave statistics of the navigation area of ship and at present the unrestricted service area is taken as the sea state of North Atlantic. After the navigation area of ship and probability level are determined, the maximum value of corresponding wave load characteristic may be obtained according to the above formula. Such value means the maximum wave load likely to occur once on average during the service period with number of cycles n.

2.3 Equivalent design wave method

2.3.1 General principle

For the structural strength assessment of ships and offshore engineering, the combination of load components is a complicated issue. The actual irregular wave is transformed to an equivalent regular wave by the equivalent design wave method, assuming that the maximum value of combined loads occurs when one of the variable loads reaches the maximum value during the service period and corresponding transient values are used for other variable loads. The method is also referred to as dynamic load method. The selected wave load components which have a deciding effect on structural strength generally include ship motion and acceleration, wave bending moment, torsional moment and shear force, sea pressure etc.

2.3.2 Determination of relevant parameters

The main steps of determination of parameters of equivalent design wave are as follows, see Figure 2-2 :

a) selection of target loads to carry out hydrodynamic analysis and calculate the response function of target loads under different headings and frequencies;

b) determination of predominant load and its probability level, carrying out spectrum analysis to solve the long-term distribution value of predominant load under the probability level;

c) determination of heading, frequency and phase of equivalent design wave in accordance with long-term statistics and response function, calculation of design wave height;

d) calculation of relevant load components of equivalent design wave in accordance with its heading, frequency, phase and wave height;
e) application of relevant loads of the equivalent design wave for structural analysis.

3 WAVE LOAD CALCULATION AND APPLICATION BASED ON EQUIVALENT DESIGN WAVE METHOD

3.1 Basic assumption and provision

3.1.1 *General*

This part specifies the basic assumption, basic calculation steps, calculation model requirements and calculation software requirements. Relevant calculation is to comply with the provisions of sub-sections.

3.1.2 *Relevant assumption*

The wave load calculation based on equivalent design wave method is based on the following assumptions:

a) based on the three-dimensional linear potential flow theory;
b) based on the wave environment of North Atlantic, and the wave scatter diagram and short-term and long-term prediction of wave loads are based on IACS Rec.34;
c) the two parameter P-M spectrum recommended by IACS Rec.34 is used as the wave spectrum;
d) the heading step is 30 deg. and the probability of occurrence of all headings are equal;
e) the calculation frequency is 0.2 rad/s to 1.2 rad/s and the frequency interval is 0.05 rad/s;
f) cos2is used as the energy transfer function of wave;
g) the strength assessment is based on 10-8 probability level and the speed is taken as 5 knots;
h) the fatigue assessment is based on 10-2 probability level and the speed is taken as 75% of the service speed.

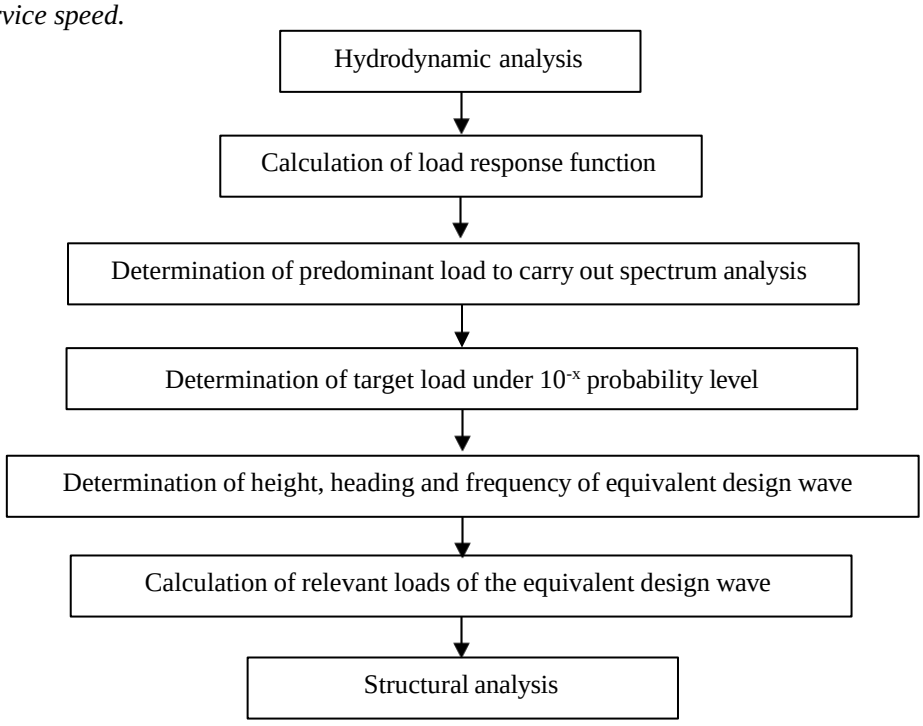


Figure 2-2 Flow Chart of Wave Load Calculation by Equivalent Design Wave Method

3.1.3 *Calculation steps*

The main steps of calculation of wave loads based on equivalent design wave method are as follows :

a) selection of loading pattern, establishment of hydrodynamic model and mass distribution model;
b) calculation of wave load response function of each heading;
c) selection of wave environment for long-term prediction of target wave load, in order to obtain the limit value and phase of relevant target load;

d) determination of parameters such as wave height, heading, frequency and phase of equivalent design wave;

e) calculation of hull girder loads, acceleration in way of ship's center of gravity and distribution of sea pressure of relevant equivalent design wave, calculation of internal pressure in accordance with position of compartment and loaded cargo.

3.1.4 ***Requirements for calculation model***

The calculation model of wave loads based on equivalent design wave method is to comply with the following requirements :

a) the mass model is to be fine enough in order to ensure that the error between mass of model and that of real ship is not greater than 0.1% and the error between position of center of gravity of model and that of real ship is not greater than 0.1%L;

b) the model of wetted surface is to simulate the shape of real ship in so far as practicable, the error between displacement of model and that of real ship is not greater than 0.1% and the error between position of center of buoyancy of model and that of real ship is not greater than 0.1%L;

c) the number of meshes of the wetted surface model is to be sufficient and the mesh length is generally not to be greater than0.01L.

3.1.5 ***Requirements for calculation software***

The calculation software of wave loads based on equivalent design wave method is to be based on the three-dimensional linear potential flow theory and approved by ISC.

3.2 Loading conditions

3.2.1 ***General requirements***

For the loading conditions for structural strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 9-1.

For the loading conditions for fatigue strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 9-1. Unless there is more accurate data, the time scale factor of corresponding loading condition is given in Section 1, Chapter 9 of PART 9-1.

3.2.2 ***Loading conditions to be considered in the strength assessment***

Loading conditions to be considered in the strength assessment prescriptive method

(1) The following loading conditions are to be considered for oil tankers:

- *a) homogeneous full load (departure);*
- *b) normal ballast condition (arrival);*
- *c) emergency ballast condition (arrival);*
- *d) other potential critical loading conditions in the loading manual.*

(2) The following loading conditions are to be considered for bulk carriers :

- *a) homogeneous heavy cargo full load (departure);*
- *b) homogeneous light cargo full load (departure);*
- *c) alternate heavy cargo full load (departure);*
- *d) alternate light cargo full load (departure);*
- *e) heavy ballast condition (arrival);*
- *f) normal ballast condition (arrival);*
- *g) other potential critical full load in the loading manual.*

Loading conditions to be considered in FE method

(1) The following loading conditions are to be considered for oil tankers fitted with one longitudinal bulkhead:

- *a) optional loading condition of 0.9 T_{SC};*
- *b) partial loading condition of 0.60 T_{SC};*
- *c) emergency ballast condition of $T_{BAL\text{-}EM}$.*

(2) The following loading conditions are to be considered for oil tankers fitted with two longitudinal bulkheads:

- *a) optional loading condition of 0.9 T_{SC};*
- *b) partial loading condition of 0.65 T_{SC};*
- *c) partial loading condition of 0.60 T_{SC};*

d) emergency ballast condition of T_{BAL-EM}.

(3) The following loading conditions are to be considered for bulk carriers:

a) homogeneous light cargo, homogeneous heavy cargo, alternate heavy cargo, alternate light cargo of T_{SC};

b) partial loading condition of $0.67T_{SC}$;

c) partial loading condition of $0.75T_{SC}$;

d) partial loading condition of $0.83T_{SC}$;

e) heavy ballast condition of T_{BAL-H}.

3.2.3 ***Loading conditions to be considered in the fatigue assessment***

Loading conditions to be considered for bulk carriers include:

a) homogeneous light cargo full load (departure);

b) homogeneous heavy cargo full load (departure);

c) heavy ballast condition (arrival);

d) normal ballast condition (arrival).

The following loading conditions are to be considered for oil tankers:

a) homogeneous full load (departure);

b) normal ballast condition (arrival).

3.3 Equivalent design wave

3.3.1 ***Introduction***

The equivalent design wave to be calculated is to represent the dynamic load cases corresponding to the most critical condition of relevant structures, mainly including the minimum and maximum of vertical bending moment of head sea and following sea amidships, the minimum and maximum of L/4 torsional moment, the minimum and maximum of pressure at waterline, the minimum and maximum of roll, the minimum and maximum of vertical acceleration of head sea and oblique sea, etc.

- *HSM load cases :*
  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- *HSA load cases:*
  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.
- *FSM load cases :*
  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- *BSR load cases :*
  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.
  BSR-1S and BSR-2S: Beam Sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.
- *BSP load cases :*
  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.
  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.
- *OST load cases :*
  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25Lfrom the AE with waves from the port side respectively.
  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25Lfrom the AE with waves from the starboard side respectively.
- *OSA load cases :*
  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.
  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

3.3.2 *Application of equivalent design wave*

The equivalent design waves to be considered for strength assessment include 7 categories, i.e. HSM, HAS, FSM, BSR, BSP, OST and OSA.

The equivalent design waves to be considered for fatigue assessment include 5 categories, i.e. HSM, FSM, BSR, BSP and OST.

3.4 Load calculation

3.4.1 *Motion and acceleration*

The roll angle θ and pitch angle φ of hull are calculated in accordance with the following formulae:

$\theta = f_{ps}\mathrm{Re}(\eta_4)$, $\varphi = f_{ps}\mathrm{Re}(\eta_5)$

The acceleration response function of any point of hull is determined from the following formulae :

$a_X = -g\sin(\varphi)+a_{surge} + (z-z_G)\bullet a_{pitch} - (y-y_G)\bullet a_{yaw}$

$a_Y = g\sin(\theta)+a_{sway} + (x-x_G)\bullet a_{yaw} - (z-z_G)\bullet a_{roll}$

$a_z = a_{heave}+(y-y_G)\bullet a_{roll} - (x-x_G)\bullet a_{pitch}$

Where,η_i (i=1,6) denotes ship motions displacements relative to the ship gravity center in six degrees of freedom, where η_{Re} is real part, η_{Im} is imaginary part,

$a_{surge}=f_{ps}\mathrm{Re}(\ddot{\eta}_1)$, $a_{sway}=f_{ps}\mathrm{Re}(\ddot{\eta}_2)$, $a_{heave}=f_{ps}\mathrm{Re}(\ddot{\eta}_3)$, $a_{roll}=f_{ps}\mathrm{Re}(\ddot{\eta}_4)$, $a_{pitch}=f_{ps}\mathrm{Re}(\ddot{\eta}_5)$,

$a_{yaw}=f_{ps}\mathrm{Re}(\ddot{\eta}_6)$

The relationship between speed $\dot{\eta}_i$ of six degrees of freedom and motion is as follows:

$$\dot{\eta}_i = i\omega_e \cdot (\eta_{i,\mathrm{Re}} + i\eta_{i,\mathrm{Im}}) = -\omega_e\eta_{i,\mathrm{Im}} + i\omega_e\eta_{i,\mathrm{Re}}, \quad \mathrm{Re}(\eta_i) = -\omega_e\dot{\eta}_{i,\mathrm{Im}}$$

The relationship between acceleration $\ddot{\eta}_1$ of six degrees of freedom and motion is as follows:

$$\ddot{\eta}_i = -\omega_e^2 \cdot (\eta_{i,\mathrm{Re}} + i\eta_{i,\mathrm{Im}}) = -\omega_e^2\eta_{i,\mathrm{Re}} - \omega_e^2\eta_{i,\mathrm{Im}}, \quad \mathrm{Re}(\eta_i) = -\omega_e^2\ddot{\eta}_{i,\mathrm{Re}}$$

where : ω_e is encounter frequency.

3.4.2 *Hull girder loads*

3.4.2.1 Hull girder still water loads

The hull girder vertical still water bending moment and vertical shear force are to taken as the permissible still water bending moment and permissible still water shear force.

3.4.2.2 Hull girder vertical wave bending moment

The hull girder vertical wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula :

$M_{WV}=f_S f_{ps} f_\beta f_m f_{nl} M_{WV,MID,MAX}$

where:

$M_{WV,MID,MAX}$ *is taken as the maximum of vertical wave bending moment between 0.4L and 0.6L in corresponding condition.*

f_m *: Distribution factor of vertical wave bending moment along ship length, as shown in Figure 3-1.*

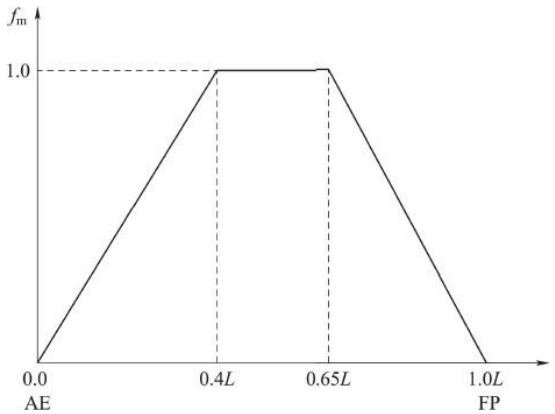


Figure 3-1 Distribution Factor f_m along the Ship's Length

The envelope of hull girder vertical wave bending moment is to be taken as the envelope of wave bending moment of all conditions.

3.4.2.3 Calculation of hull girder vertical wave shear force

For a given loading condition, the wave shear force at any section under any equivalent design wave is to be taken as:

$$Q_{WV} = f_{ps} f_{\beta} f_q f_{lp} Q_{WV,MAX}$$

where:

f_q *: distribution factor of vertical wave shear force, to be taken as* $f_{q\text{-}pos}$ *if it is greater than or equal to zero, see Figure 3-2 and* $f_{q\text{-}neg}$ *if it is less than zero, see Figure 3-3;*

f_{lp}*: coefficient for symbol of vertical wave shear force,* f_{lp} *=1.0 for hogging and* $x/L<0.5$*, or sagging and* $x/L \geqslant 0.5$*, otherwise* f_{lp} *=-1.0;*

$Q_{WV,MAX}$*: to be taken as* $MAX\left[\frac{MAX\left|Q_{WV,CAL,A,i}\right|}{0.92}, \frac{MAX\left|Q_{WV,CAL,F,i}\right|}{1.0}\right]$*, where* $Q_{WV,CAL,A,i}$ *is calculation value of wave shear force of each section when* $x/L<0.5$ *and* $Q_{WV,CAL,F,i}$ *is calculation value of wave shear force of each section when* $x/L \geqslant 0.5$*.*

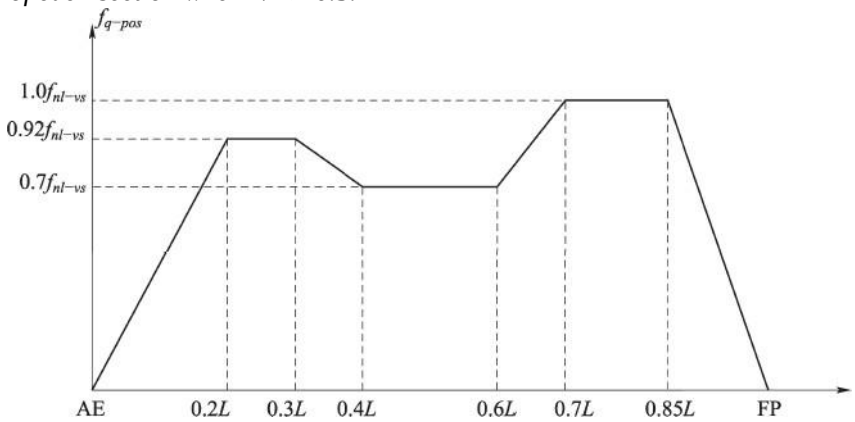


Figure 3-2 Distribution Factor $f_{q\text{-}pos}$ along the Ship's Length

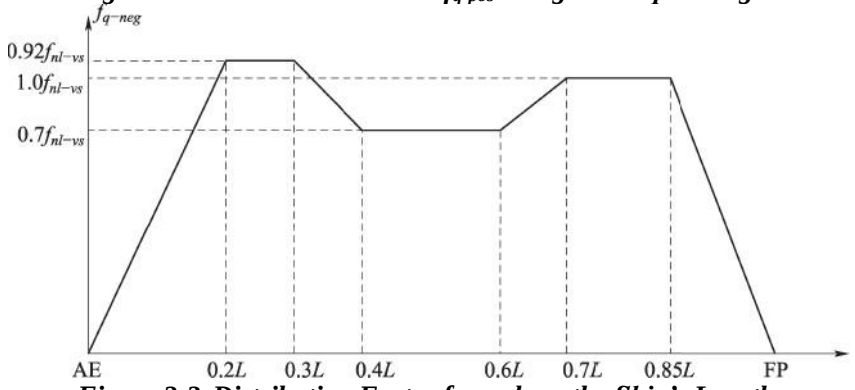


Figure 3-3 Distribution Factor $f_{q\text{-}neg}$ along the Ship's Length

3.4.2.4 Hull girder horizontal wave bending moment

The hull girder horizontal wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula :

$$M_{WH} = f_S f_{ps} f_b f_m f_{nlh} M_{WH,MID,MAX}$$

where:

f_{nlh}*: Coefficient considering nonlinear effect to be taken as:*

f_{nlh} *= 0.9* *for strength assessment*

f_{nlh} *= 1.0* *for fatigue assessment*

$M_{WH,MID,MAX}$ *is the maximum of horizontal wave bending moment between 0.4L and 0.6Lunder the equivalent design wave.*

3.4.2.5 Hull girder wave torsional moment

The hull girder torsional moment is considered for only OST and OSA cases for each loading condition and is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The value between any two calculation points is obtained by linear interpolation, taking into account the correction of f_β *.*

$M_{WT} = f_{ps} f \ M_{WT,\,CAL}$

3.4.3 *Sea pressure*

3.4.3.1 Hydrostatic pressure

The hydrostatic pressure is calculated in accordance with the following formula, but not to be less than zero :

$P_{es}=\rho g(T_{LC} - z)$

3.4.3.2 Hydrodynamic pressure

The wave dynamic pressure of any point of section under equivalent design wave specified by each loading condition is to be taken as the linear fitted value of pressure of three points of bottom centre line point, bilge calculation point and water line point, but is not to be less than - $\rho g(T_{LC} - z)$ *below the water line and not less than zero above the water line, i.e. :*

$P_{ed} = f_{ps} f_{nl-p} [P_{ctr} + \frac{y}{y_{bilge}} (P_{bilge} - P_{ctr})]$, *between bottom centre line point and bilge calculation point;*

$P_{ed} = f_{ps} f_{nl-p} [P_{bilge} + \frac{z - z_{bilge}}{T_{LC} - z_{bilge}} (P_{WL} - P_{bilge})]$, *between bilge calculation point an water line point;*

$P_{ed} = f_{ps}\, f_{nl\text{-}p}\, [P_{WL}\text{-}10(z\text{-}T_{LC})]$, *above the water line, for strength assessment.*

$P_{ed} = f_{ps}\, f_{nl\text{-}p} [P_{WL}\text{-}5(z\text{-}T_{LC})]$, *above the water line, for fatigue assessment.*

Where,

y_{bilge} *and* z_{bilge} *: the coordinate Y and Z of the bilge calculation point as referring to the figure 3-4.*

$f_{nl\text{-}p}$ *:Coefficient considering nonlinear effects applied to hydrodynamic pressure. For strength assessment, see the definition in Part 9-1, Ch 4, Sec 5. For fatigue assessment, it is taken as 1.0.*

The pressure of three points of bottom centerline point, bilge calculation point and water line point is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The interpolation function between any two section is to be taken as the cubic function determined by four calculation points nearby.

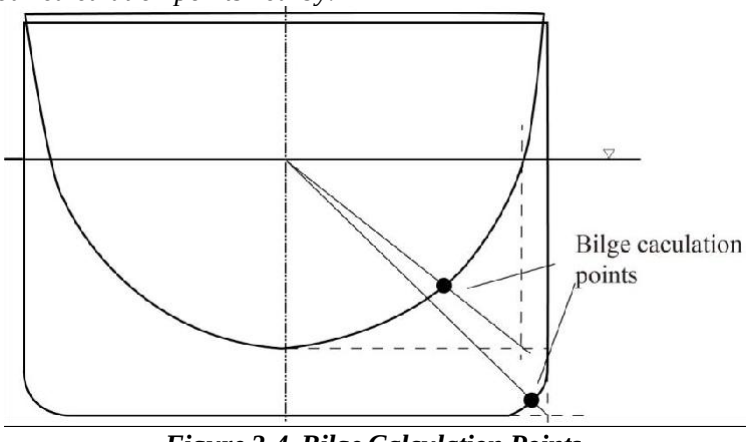


Figure 3-4 Bilge Calculation Points

3.4.3.3 Total sea pressure

The total sea pressure is calculated in accordance with the following formula, but not to be less than zero:

$P_{ex} = P_{es} + P_{ed}$

3.4.4 *Pressure in tanks*

3.4.4.1 Liquid pressure in tanks

The static liquid pressure in tanks P_{ls} is calculated in accordance with 1.2, Section 6, Chapter 4 of PART 9-1.
The dynamic liquid pressure in tanks P_{ld} is calculated in accordance with 1.3, Section 6, Chapter 4 of PART 9-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.2 Dry bulk cargo pressure in tanks
The calculation formulae of dry bulk cargo static pressure P_{bs}, dynamic pressure P_{bd}, static shear load $P_{bs\text{-}s}$ and dynamic shear loads $P_{bs\text{-}d}$, $P_{bs\text{-}dx}$, $P_{bs\text{-}dy}$ are given in 2, Section 6, Chapter 4 of PART 9-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.3 Total internal pressure
The total internal pressure P_{in} is to be taken as the sum of static and dynamic pressure of liquids or dry bulk cargoes in tanks, but not to be less than zero.

3.5 Application of relevant loads
3.5.1 ***Correspondence between relevant loads and PART 9-1***

Corresponding load pa rameters between Appendix A and Part 1 Table1

Name of load	*Symbol of the Rules*	*Paragraph of definition in PART 9-1*	*Symbol of this Appendix*	*Paragraph of this Appendix*
Roll angle	θ	*Symbols, Section 3, Chapter 4*	θ	*3.4.1*
Pitch angle	φ	*Symbols, Section 3, Chapter 4*	φ	*3.4.1*
Acceleration at any point	a_X a_Y a_Z	*Table 4, Section 4, Chapter 1*	a_X a_Y a_Z	*3.4.1*
Vertical wave bending moment	$M_{wv\text{-}LC}$	*3.5.2, Section 4, Chapter 4*	M_{wv}	*3.4.2.2*
Vertical wave shear force	$Q_{wv\text{-}LC}$	*3.5.3, Section 4, Chapter 4*	Q_{wv}	*3.4.2.3*
Horizontal wave bending moment	$M_{wh\text{-}LC}$	*3.5.4, Section 4, Chapter 4*	M_{WH}	*3.4.2.4*
Wave torsional moment	$M_{wt\text{ - }LC}$	*3.5.5, Section 4, Chapter 4*	M_{WT}	*3.4.2.5*
Total sea pressure	P_{ex}	*Table 4, Section 4, Chapter 1*	P_{ex}	*3.4.3.3*
Hydrostatic pressure	P_S	*1.2.1, Section 5, Chapter 4*	P_S	*3.4.3.1*
Hydrodynamic pressure	P_W	*1.3 and 1.4, Section 5, Chapter 4*	P_W	*3.4.3.2*
Total internal pressure	P_{in}	*Table 4, Section 4, Chapter 1*	P_{in}	*3.4.4.3*
Static liquid pressure	P_{ls}	*1.2, Section 6, Chapter 4*	P_{ls}	*3.4.4.1*
Dynamic liquid pressure	P_{ld}	*1.3, Section 6, Chapter 4*	P_{ld}	*3.4.4.1*
Dry bulk cargo static pressure	P_{bs}	*2.4.2, Section 6, Chapter 4*	P_{bs}	*3.4.4.2*
Dry bulk cargo dynamic pressure	P_{bd}	*2.4.3, Section 6, Chapter 4*	P_{bd}	*3.4.4.2*

3.5.2 ***Application of relevant loads in prescriptive methods***

3.5.2.1 Hull girder strength

The still water bending moment and shear force for hull girder strength assessment are to use relevant permissible values.

The envelope of vertical wave bending moment and shear force for hull girder strength assessment is taken as the value calculated in accordance with 3.4.2.2 and 3.4.2.3 of this Appendix.

3.5.2.2 Yielding and buckling strength

The design load sets for assessment of yielding and buckling strength are given in Table 1, Section 2, Chapter 6 of PART 9-1, and relevant loads are given in this Appendix.

3.5.2.3 Fatigue strength of longitudinals

The assessment of fatigue strength of longitudinals is given in Section 4, Chapter 9 of PART 9-1, and relevant loads are given in this Appendix.

3.5.3 ***Application of relevant loads in FE methods***

3.5.3.1 Strength assessment

Loading conditions and dynamic load cases for FE strength assessment are given in 1 to 4, Section 8, Chapter 4 of PART 9-1, and relevant loads are given in this Appendix.

3.5.3.2 Fatigue assessment

Loading conditions and dynamic load cases for FE fatigue assessment are given in 5, Section 8, Chapter 4 of PART 9-1, and relevant loads are given in this Appendix.

ISC Appendix B SUPPLEMENTARY REQUIREMENTS FOR DIRECT CALCULATION LOAD CONDITIONS

1 GENERAL

1.1 General requirements

1.1.1

Direct calculation of load conditions for special structural arrangement in compliance with the requirements of 2.5.1 of Section 8, Chapter 4 of PART 9-1 is to be carried out according to the requirements of this Appendix.

1.1.2

This Appendix specifies the general principles for determining the direct calculation load conditions for the above mentioned special structural arrangement and direct calculation conditions for specific structural arrangement.

1.1.3

The structural FE model and boundary conditions, calculation and applying of loads, loads adjustment, calculation criteria included in this Appendix are to comply with the requirements for direct calculation in Chapter 7 of PART 9-1.

1.2 Application

1.2.1

This Appendix is applicable to double or single hull bulk carriers and oil tankers with one or two longitudinal bulkhead in compliance with the requirements of PART 9-1.

1.2.2

The direct calculation load conditions as specified in this Appendix are only applicable to structural strength assessment.

1.3 Symbols and definitions

1.3.1

The parameters and symbols used in this Appendix are those defined in Chapter 4 of PART 9-1.

2 GENERAL PRINCIPLES

2.1 General requirements

2.1.1

The types and density of dry bulk cargo, density of cargo oil, density of ballast water and fuel oil are to comply with the requirements of Chapter 4 of PART 9-1.

2.1.2

Typical loading patterns (departure, arrival, harbour, partially filled ballast tanks) are to comply with the requirements of Section 8, Chapter 4 of PART 9-1.

2.1.3

The loading condition and draught are to comply with the requirements of Section 8, Chapter 4 of PART 9-1 and the worst loading pattern is to be selected as the case to be checked according to the actual situation specified in the loading manual.

2.2 Principles for selection of loading condition

2.2.1

Oil tankers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 9-1, including:

(1) heavy ballast condition where all ballast tanks may be full, partially full or empty, 100% filling of fore peak water ballast tanks;

(2) other seagoing conditions in loading manual where these differ significantly from the ballast conditions;

(3) any specified non-uniform distribution of loading.

2.2.2

Bulk carriers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 9-1, including:

(1) homogeneous light and heavy cargo loading conditions
(2) alternate loading conditions;
(3) multiport loading conditions, where applicable;
(4) alt-block loading conditions, where applicable;
(5) load case where heavy ballast conditions of designated heavy ballast hold or normal ballast condition in case of no heavy ballast hold, including ballasting of fore peak tank.

2.2.3 Special structural arrangement loading conditions

(1) Loading pattern

In general, cargo tanks and dry bulk cargo holds in cargo tank/hold region are to comply with the requirements for typical structural arrangement as specified in PART 9-1. Where the arrangement of cargo hold or double hull mid hold (ballast tank or fuel oil tank) is inconsistent with the typical structure as specified in PART 9-1, the loading pattern is to be defined according to the requirements of Section4,Chapter 8 of PART 9-1 and the actual location of cargo hold or double hull mid hold.

(2) Draught

Draught of oil tanker in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 9-1. For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 L or tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11L. The load case draught is to be taken the draught as required by the Rules or the actual draught in loading manual. Generally, the draught which imposes more severe effect to the structural strength is to be selected.

Draught of bulk carriers in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 9-1.

(3) Target location for hull girder shear force adjustment

The cargo hold region selected for direct calculation model is to be arranged with 3 cargo holds and 4 transverse bulkheads. The shear force is to be adjusted at target bulkhead in alternate loading conditions included in load cases in case of special structural arrangement.

3 TYPICAL ADDITIONAL LOADING CONDITIONS

3.1 Oil tankers

3.1.1

There are in general various forms of arrangement for the slop tank in the aftmost region of cargo tank in oil tankers. In addition to the general arrangement as given in Section 8, Chapter 4 of PART 9-1, typical arrangements for slop tank of oil tankers are shown in Figure 3.1.1(1) and Figure 3.1.1(2).

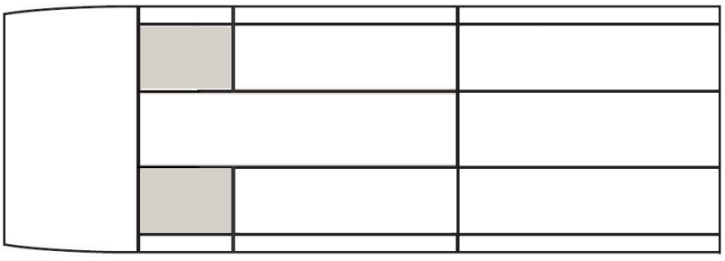


Figure 3.1.1(1) Typical arrangement for slop tank-1

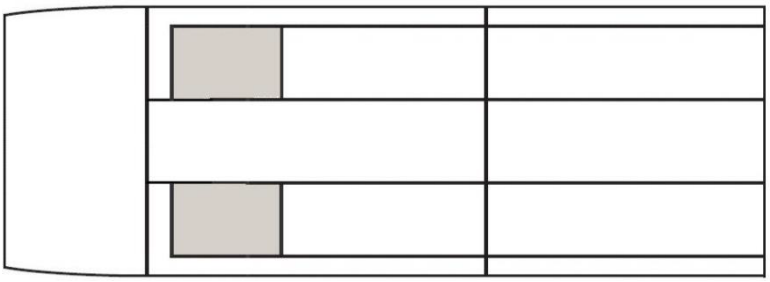
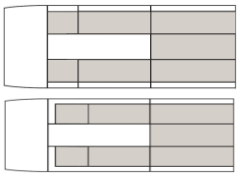
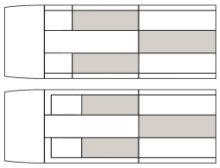


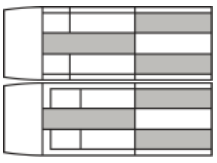
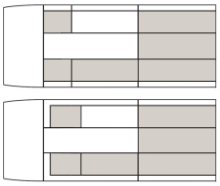
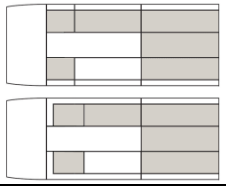
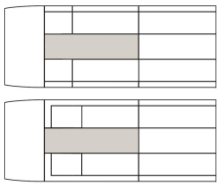
Figure 3.1.1(2) Typical arrangement for slop tank-2

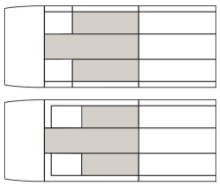
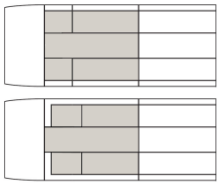
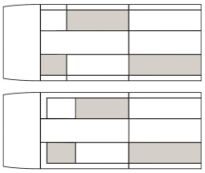
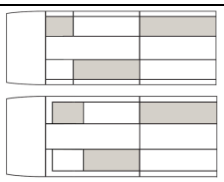
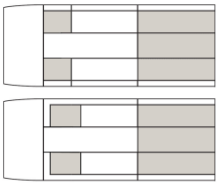
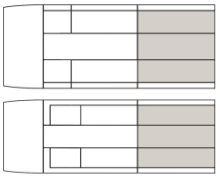
3.1.2

The load cases for the above mentioned arrangement for slop tank are shown in Table 3.1.2.

Load Cases ***Table 3.1.2***

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
Seagoing Conditions					
A1[4]		*0.9T_{SC}*	*100% (sagging)*	*100%*	*all LC*[2]
			100% (hogging)	*100%*	*all LC*[2]
A2[4]		*0.9T_{SC}*	*100% (sagging)*	*100%*	*all LC*[2]
			100% (hogging)	*100%*	*all LC*[2]
A3-1[1][3]		*0.65T_{SC}*	*100% (hogging)*	*100% Max SFLC*	*HSM-2 FSM-2*
				100%	*Group 2 LC*[9] *except HSM-2, FSM-2*
			100% (sagging)	*100% Max SFLC*	*HSM-1 FSM-1*
				100%	*Group 1 LC*[8] *except HSM-1, FSM-1*
A3-2[1][4]		*0.65T_{SC}*	*100% (hogging)*	*100% Max SFLC*	*HSM-2 FSM-2*
				100%	*Group 2 LC*[9] *except HSM-2, FSM-2*
			100% (sagging)	*100% Max SFLC*	*HSM-1 FSM-1*
				100%	*Group 1 LC*[8] *except HSM-1, FSM-1*
A4[3]		*0.6T_{SC}*	*100% (sagging)*	*100%*	*all LC*[1]

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
A5-1[3]		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2 LC[9] except HSM-2, FSM-2
A5-2[4]		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8]except HSM-1, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2 LC[9] except HSM-2, FSM-2
A6[4]		$0.6T_{SC}$	100% (hogging)	100%	all LC [1]
A7a[4]		T_{LC}	100% (hogging)	100%	all LC [1]
A7b[4]		T_{LC}	100% (hogging)	100%	all LC [1]
Harbour and testing conditions					
A10[4]		$0.25T_{SC}$	100% (sagging)	100%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
A11-1[3]		$0.6T_{SC}$	100% (sagging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A11-2[4]		$0.6T_{SC}$	100% (sagging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A12a[5]		$0.33T_{SC}$	N/A	N/A	N/A
A12b[5]		$0.33T_{SC}$	N/A	N/A	N/A
A13-1[3]		$0.65T_{SC}$	100% (hogging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A13-2[4]		$0.33T_{SC}$	100% (hogging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A14[4]		T_{SC}	100% (hogging)	100%	N/A

Notes:

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.

(2) "All LC" means: all the dynamic load cases as defined in Ch 4, Sec 2 for both sagging and hogging and both P and S.

(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.

(4) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward

machinery space bulkhead.

(5) The shear force and bending moment that results from the application of local loads are to be used for non-hull girder adjustment conditions.

(6) The shear force is to be adjusted to target value at forward machinery bulkhead.

(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(8) Group1 LC means: all Head sea LC in sagging, all Following sea LC in sagging, all Beam Sea LC and all Oblique Sea load cases.

(9) Group2 LC means: all Head sea LC in hogging, all Following sea LC in hogging, all Beam Sea LC and all Oblique Sea load cases.

3.1.3

In addition to the above mentioned typical tank arrangement, the general principles for determining the target location of shear force adjustment are as follows in cases there are other special arrangement for cargo tank, slop tank and ballast tank in the aftmost region of oil tanker.

(1) in general, the forward machinery bulkhead is to be taken as the reference location;

(2) where alternate loading condition is taken for slop tank an adjacent cargo tank, forward bulkhead of slop tank is to be taken as the reference location.

3.2 Bulk carriers

3.2.1

Special arrangement for the double hull tanks (fuel oil tank, ballast tank, empty tank) of bulk carriers are shown in Figure 3.2.1.

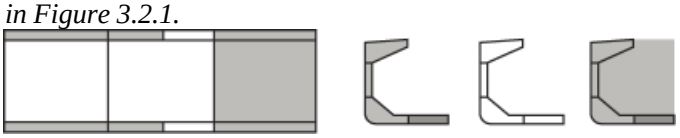
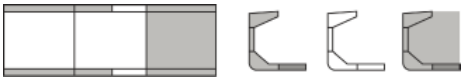


Figure 3.2.1 Special arrangement for bulk carriers

3.2.2

For special arrangement as shown in Figure 3.2.1, load cases are to be supplemented according to Table 3.2.2 for heavy ballast condition in addition to the load cases as required in Section 8 of Chapter 4.

Additional load cases in heavy ballast conditions ***Table 3.2.2***

No.	*Description*	*Loading pattern Aft Mid Fore*	*Draught*	*% of perm. SWBM*	*% of perm. SWSF*	*Dynamic load case*
Seagoing conditions						
1	*Deepest Ballast (4.2.1 of Section 8, Chapter 4 of PART 9-1)*		*THB*	*100% (hogging)*	*100%(1)*	*FSM-2 BSR-1P, BSR-1S OST-2P, OST-2S*
				100% (sagging)	*100%(1)*	*BSP-1P, BSP-1S BSR-1P, BSR-1S, OST-1P, OST-1S*

Note:

(1) The shear force is to be adjusted to target value at watertight transverse bulkhead of double hull ballast tank of the mid-hold.

ISC Appendix C ASSESSMENT OF ULTIMATE STRENGTH OF HULL GIRDERS USING NON-LINEAR FEM

1 GENERAL

1.1 Application

1.1.1

The non-linear finite element method for assessment of the ultimate strength of hull girders, as provided in this Appendix, is applicable to the assessment of the ultimate strength of intact hull girders and damaged hull girders after collision/grounding.

1.1.2

For the hull girder FE models in this Appendix, the relevant non-linear effects given in paragraph 3.1.1, Appendix 2, Chapter 5 of PART 9-1 of the Rules are to be taken into account.

2 SINGLE SPAN FE MODEL

2.1 Application

2.1.1

The longitudinal extent of the single span FE model is one span of transverse web frames, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth.

2.1.2

The FE model is to cover all longitudinal continuous members and the stiffeners having an influence on local buckling.

2.1.3

The FE model is to take into account manholes and lightening holes in hull structures.

2.1.4

The FE model is to use net scantlings, i.e. the as-built scantlings deducted by half the corrosion addition. For corrosion addition, see Section 3, Chapter 3 of PART 9-1 of the Rules.

2.1.5

For the stress-strain curve of hull structural materials, a bilinear model is to be used taking into account the strain-hardening effects.

2.2 Finite element types and meshing

2.2.1

4-nodes shell elements are to be used for plates, stiffeners and primary supporting members, and beam elements may also be used for stiffener flanges and for web stiffeners of primary supporting members.

2.2.2

The mesh size of the FE model is to be such that local buckling deformations and stress redistribution after localized plastic collapse of structural members (including plating, stiffeners, primary supporting members, etc.) is sufficiently presented. Meshes are to be square as far as possible.

2.3 Initial geometric imperfections

2.3.1

For all longitudinal members of the FE model, the initial geometric imperfections, which may lead to the most critical failure of hull girders, are to be considered.

2.3.2

For the mode of initial geometric imperfections, the overall deformations of stiffened plates between web frames, local deformation of plating and sideways initial deformations of stiffeners

are to be considered.

2.3.3
For the amplitude of initial geometric imperfections, deformations from welding or assembly are to be taken into account.

2.4 Boundary conditions and loading
2.4.1
An independent point is to be established at the intersection of neutral axis of cross sections of fore and aft ends of the model respectively.

2.4.2
The two independent points are to be related to the nodes on fore end and aft end of the model respectively, and simply supported restraints are to be applied to the independent points.

2.4.3
An equal hogging/sagging bending moment (or rotation angle) is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

2.4.4
When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

2.5 Damages due to collision and grounding
2.5.1
For assumptions regarding damage extents, see paragraph 2.2, Section 3, Chapter 5 of PART 9-1.

2.6 Checking criteria
2.6.1
When single span FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

3 CARGO HOLD FE MODEL
3.1 General
3.1.1
The longitudinal extent of a cargo hold FE model is the length of one cargo compartment, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth, taking into account the effects of lateral loads (including both internal and external loads).

3.1.2
The cargo hold FE model is to cover all transverse members other than transverse bulkheads, upper and lower stools.

3.1.3
Other requirements for the cargo hold FE model are given in paragraphs 2.1.3 to 2.1.6.

3.2 Finite element types and meshing
3.2.1
The requirements for meshing of the cargo hold FE model are given in paragraph 2.2.

3.3 Initial geometric imperfections
3.3.1
The requirements for initial geometric imperfections of the cargo hold FE model are given in paragraph 2.3.

3.4 Lateral loads

3.4.1
The lateral loads in both full load and ballast conditions are to be considered. For bulk carriers, the lateral loads in alternate loading conditions are also to be considered, if applicable.

3.5 Boundary conditions and loading
3.5.1
The boundary conditions for the cargo hold FE model are given in paragraphs 2.4.1and 2.4.2.

3.5.2
The lateral loads specified in paragraph 3.4.1 are to be applied to the FE model.

3.5.3
An equal hogging/sagging bending moment (or rotation angle)is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

3.5.4
When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

3.6 Damages due to collision and grounding
3.6.1
For assumptions regarding vertical and transverse damage extents, see paragraph 2.2, Section 3, Chapter 5 of PART 9-1, and special consideration is to be given to the longitudinal damage extent.

3.7 Checking criteria
3.7.1
When the cargo hold FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

ISC Appendix D RECOMMENDATION FOR ASSESSING DESIGN INSTANCES BASED ON APPLICATION OF ALTERNATIVE METHODS IN THE HULL STRUCTURAL DESIGN OF CSR SHIPS

1 GENERAL

1.1

This Appendix is applied to this PART of ISC Rules for Classification of Sea-going Steel Ship and gives recommendations for assessing alternative (novel) design instance and alternative (novel) design method (technology).

2 SCOPE

2.1

The scope of this Appendix is to provide guidance for the assessment of alternative (novel) design instances and designs in compliance with requirements of this PART of ISC Rules for Classification of Sea-going Steel Ship, based on the application of alternative (novel) design method (technology) or alternative design and calculation methods within the context of Goal Based Standards and this PART of ISC Rules for Classification of Sea-going Steel Ship.

3 DEFINITIONS

3.1 Alternative (novel) design instance

An alternative or a novel design instance is defined via ISC Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch 1 Sec 3 [6.2.1] i.e. ship design of unusual form, proportions, speed and structural arrangements outside those specified in Part 9-1 Ch 1, Sec 2, [3.2].

Design instances covered by additional class notations or additional class requirements (e.g. strengthening for operation in ice) are not considered alternative or novel design instances.

For ships not complying with ISC Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch1 Sec 2 [3.2], Part 9-1 Ch1 Sec 2 [ISC 3.2.1a] and ISC Appendix A of Part 9-1 are to be applied.

3.2 Alternative (novel) design method (technology)

An alternative design method or alternative design technology is a method or technology applied in the design process that has no/limited documented track record for application in this field. This means that there is no documentation that can be arranged by the designers to prove with confidence that the outcome or result of the method (or technology) e.g. scantlings of hull structural elements or fatigue assessment of structural details, will be equivalent to a design based on the requirements of this Part of ISC Rules for Classification of Sea-going Steel Ship.

4 APPLICATION

4.1

The scantlings determined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as FE analysis, unless explicitly stated. (ISC Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch 1 Sec 2 [5.5.4])

4.2

Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantling and arrangements are of at least equivalent strength to those derived using the Rules.

5 EQUIVALENCE PRINCIPLE

5.1

For the application of alternative methods in the design, the main principle is to get sufficient evidence, and verify such evidence, that the resulting alternative design instance is equivalent (i.e. has at least the same structural safety level) to a design instance compliant to this Part.

6 ASSESSMENT OF ALTERNATIVE(NOVEL) DESIGN INSTANCES

6.1 General

The handling of alternative(novel) design instances should follow as far as practicable the

procedures given in ISC Circular No.498 " The Notice on the approval of IMO MSC.1/Circ.1455"[(1)].
Deviations from this PART of ISC Rules for Classification of Sea-going Steel Ship and/or other requirements that are proven to be in compliance with IMO Goal Based Standards may have impact on the compliance of the design with SOLAS Reg II-1/3-10. Therefore, a flag Administration need to consider the statutory approval of an alternative (novel) design instance in this case.

6.2 Role of the Classification Society
ISC reviews the delivered documentation; states further requirements for documentation if necessary, can request verification of achieved results and eventually grants approval.
This means that ISC is to assess whether the design has been sufficiently examined and whether any risks have been reduced acceptably and to evaluate the adequacy of the delivered information and the assumptions made. ISC is to make the final decision for applying ISC Circular No.498 to approve equivalency to this Part of ISC Rules for Classification of Sea-going Steel Ship of the alternative (novel) design instance, and the final responsibility of class approval for the design instance rests with ISC.
The task and role of ISC is to verify that - based on submitted information from the designer / shipyard - the design instance is in compliance with this Part of ISC Rules for Classification of Sea-going Steel Ship or its structural safety level is at least equivalent to that ensured by the requirements given in this Part of ISC Rules for Classification of Sea-going Steel Ship.

7 DESCRIPTION OF ALTERNATIVE DESIGN AND CALCULATION METHODS USED IN THE HULL STRUCTURAL DESIGN

7.1 General
Alternative design and calculation methods may be applied to the extent specified in this Part of ISC Rules for Classification of Sea-going Steel Ship for:
(1) Improvement of the design process
(2) Optimization of the hull structure (weight of the structure, improvements in fabrication, etc.)
This Part allows explicitly the application of alternative design and calculation methods in the following paragraphs:

Procedure for alternative design or calculation methods ***Table 1***

Rule reference	*Details*	*Alternative design / calculation method*	*Detail procedure in this Part*
Pt 9-1, Ch 5, Appendix 2	*Hull girder ultimate capacity*	*Direct non-linear finite element analysis*	*Yes, Part 9-1, ISC Appendix C*
Pt 9-1, Ch 6, Sec 6, [2.2.2]	*Primary supporting members within cargo region for bulk carrier less than 150 m*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 9, Sec 1, [4.5]	*Fatigue design standards for alternative design*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 9, Sec 4, [5.3]	*Stress concentration factors for alternative design*	*FEA (Finite Element Analysis)*	*Yes, detail FEA procedure in [5.3.1]*
Pt 9-1, Ch 9, Sec 6, [2.2]	*Equivalent design of stiffener-frame connections*	*FEA (Finite Element Analysis)*	*Yes, detail FEA procedure in [2.2]*

[1] *Note (1): ISC Circular No.498 is the transformation of the International Maritime Organization "the Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments" (refer to IMO MSC.1/Circ.1455).*

Rule reference	*Details*	*Alternative design / calculation method*	*Detail procedure in this Part*
Pt 9-1, Ch 10, Sec 1, [2.3.3]	*The spacing of web frames and stringers iwo side shell*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 10, Sec 3, [2.1.4]	*The spacing and arrangement requirements*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 11, Sec 1, [3.2.5]	*Arrangements of deck girders and transverses*	*Grillage or FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-2, Ch 1, Sec 4, [4.1.2]	*Primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a length L less than 150 m*	*Grillage or FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-2, Ch 2, Sec 3, [1.5.4]	*Deck transverses fitted above the upper deck*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*

The application of alternative design and calculation methods should result in a design instance compliant with this Part of ISC Rules for Classification of Sea-going Steel Ship.
ISC should assess the resulting design instance with respect to compliance with the rules. Assessment of the alternative design and calculation method used for the design is not necessary.
The requirements in Section 6 and Section 8 of this Appendix should be followed only in case the application of alternative design method results in alternative (novel) design instance.

8 DUCUMENTATION

8.1

Documentation provided with an application for alternative (novel) design method (technology) used in the hull structural design as equivalency should identify the detail of the methods that have been undertaken, the equivalent safety level and the sufficient supporting information to validate assessments as well as the resulting scantlings, materials, etc.

8.2

In case of a ship where alternative methods are applied and an equivalency for the alternative (novel) design instance is considered by ISC, this should be noted in the relevant structural drawings and/or appropriate approval documents as required by ISC's procedures. The documentation on the application of alternative methods should be included in the Ship Construction Files (SCF) in accordance with the requirement in ISC Rules for Classification of Sea-going Steel Ships Part 1, Chapter 4, Appendix 1, Annex 2, [3.1.1], (3)[(2)].

[2] *Note (2): The requirement is incorporation of IACS Unified Requirement (UR) Z23.*

Chapter 1 BULK CARRIERS

Section 1 GENERAL ARRANGEMENT DESIGN

1 FORECASTLE

1.1 General

1.1.1

An enclosed forecastle is to be fitted on the freeboard deck.

The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 1.However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length for freeboard as specified in Pt 1, Ch 1, Sec 4, [3.1.2] abaft the fore side of stem.

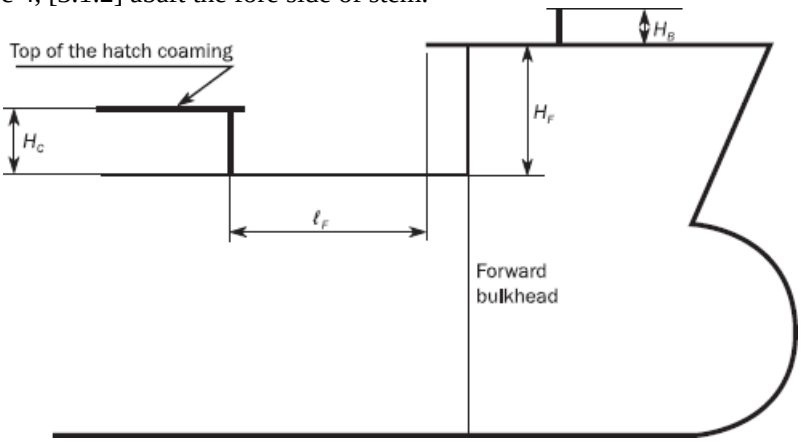


Figure 1 Forecastle arrangement

1.1.2

The forecastle height, *HF* above the main deck is not to be less than the greater of the following values:

- The standard height of a superstructure as specified in Pt 1, Ch 1, Sec 4, [3.3].
- H_C + 0.5 m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1.

1.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to l_F, taken as:

$$l_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate.

1.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B / tan 20°forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle, see Figure 1.

2 ACCESS ARRANGEMENTS

2.1 Special arrangements for bulk carriers

2.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other.

The aft access may lead from the engine room to the duct keel. Where an aft access is provided from the engine room to the duct keel, the access opening to the duct keel is to be provided with

watertight hatch cover, cover plate or door.
Ventilation may be aided by the use of mechanical means as required.

2.1.2
Where a watertight door is fitted for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society.

Section 2 STRUCTURAL DESIGN PRINCIPLES

SYMBOLS
For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

1 APPLICATION

1.1

1.1.1

This section applies to structures in all parts of bulk carriers, in addition to requirements given in Pt 1, Ch 3, Sec 6.

2 CORROSION PROTECTION

2.1 General

2.1.1 Void double side skin spaces

Void double side skin spaces are to have a corrosion protective system fitted in accordance with [2.2].

2.1.2 Cargo holds and ballast holds

Cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with [2.3].

2.2 Protection of void double side skin spaces

2.2.1

Void double side skin spaces in the cargo area for ships having a freeboard length L_{LL} of not less than 150 m are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent.

2.3 Protection of cargo hold spaces

2.3.1 Coating

It is the responsibility of the builder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

2.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.
The side and transverse bulkhead areas to be coated are specified in [2.3.3] and [2.3.4] respectively.

2.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- The inner side plating.
- The internal surfaces of the topside tank sloping plates.
- The internal surfaces of the hopper tank sloping plates for a distance of 300 mm below the frame end bracket for holds of single side skin construction, or below the hopper tank upper end for holds of double side skin construction.

These areas are shown in Figure 1.

2.3.4 Transverse bulkhead areas to be coated

The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

3 STRUCTURAL DETAIL PRINCIPLES

3.1 Double bottom structure

3.1.1 Application

In addition to the requirements provided in Pt 1, Ch 2, Sec 3, [2], the requirements of this sub-article are applicable to the following ships:

- All bulk carriers with freeboard length L_{LL} less than 150 m,
- Bulk carriers having a freeboard length L_{LL} of 150 m or above, with one or more cargo holds arranged for carriage of water ballast.

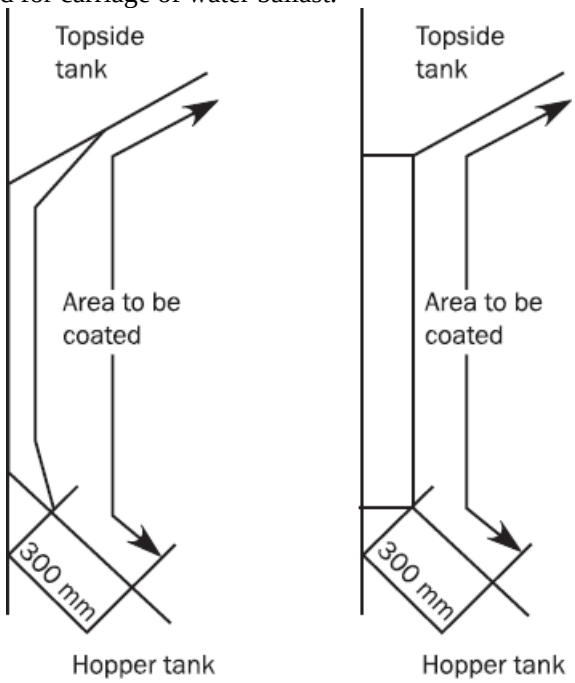


Figure 1 Side areas to be coated

3.1.2 Double bottom height

Height of double bottom in cargo area, d_{DB}, in m, measured from keel line at mid-length of each cargo hold is not to be less than:

$$d_{DB} = 32B + 190\sqrt{T_{SC}}$$

A lower double bottom height may be accepted, provided all of the following requirements are satisfied:

- The spacing of adjacent girders is not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.
- The spacing of floors is not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.1.3 Girder spacing

The spacing of adjacent girders is generally not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.

3.1.4 Floor spacing

The spacing of floors is generally not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.2 Single side structure

3.2.1 Application

This article applies to the single side structure with transverse framing of single side bulk carrier. If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in Pt 1, Ch 3, Sec 6, [8] apply to these primary supporting members as regarded to ones in double side skin.

3.2.2 General arrangement

Side frames are to be arranged at every frame space.

If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

3.2.3 Side frames

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r, in mm, given by:

$$r = \frac{0.4 b_f^2}{t_f + t_c}$$

where:

t_c : Corrosion addition, in mm, specified in Pt 1, Ch 3, Sec 3.

b_f, t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

The dimensions of side frames are defined in Figure 2.

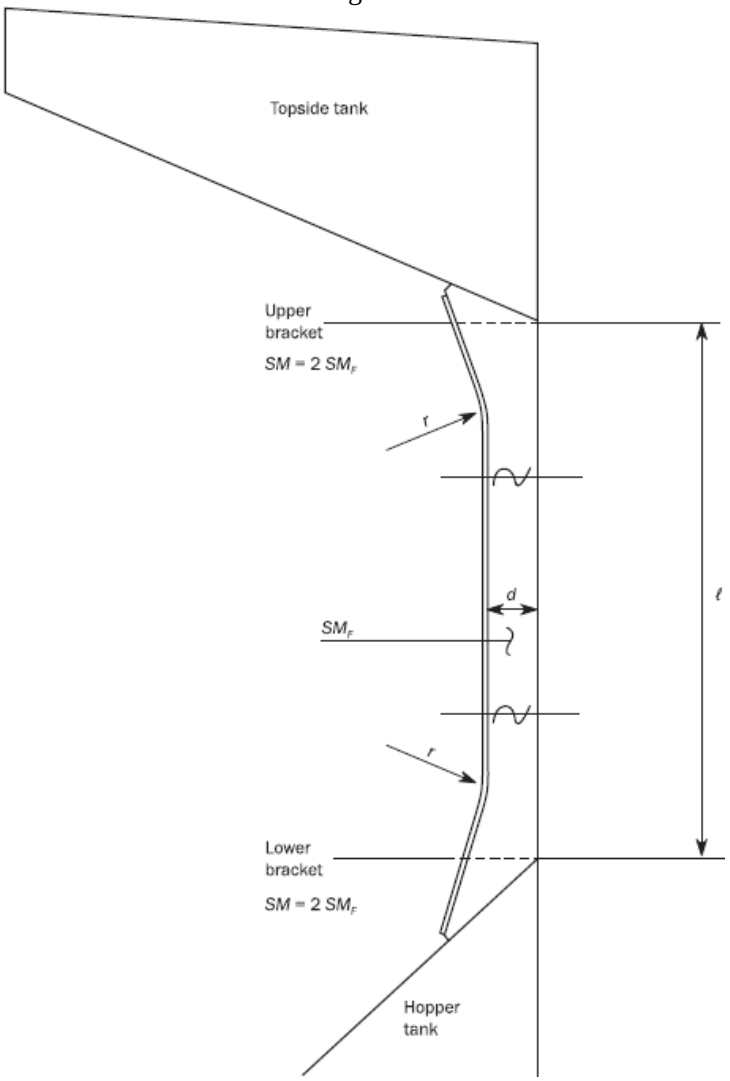


Figure 2 Dimensions of side frames

3.2.4 Upper and lower brackets

The face plates or flange of the brackets is to be sniped at both ends. Brackets are to be arranged with soft toes. The as-built thickness of the brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.
The dimensions (in particular the height and length) of the lower brackets and upper brackets are not to be less than those shown in Figure 3.

3.2.5 Tripping brackets

In way of the foremost hold and in the holds of BC-A ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in Figure 4.
The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.
Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

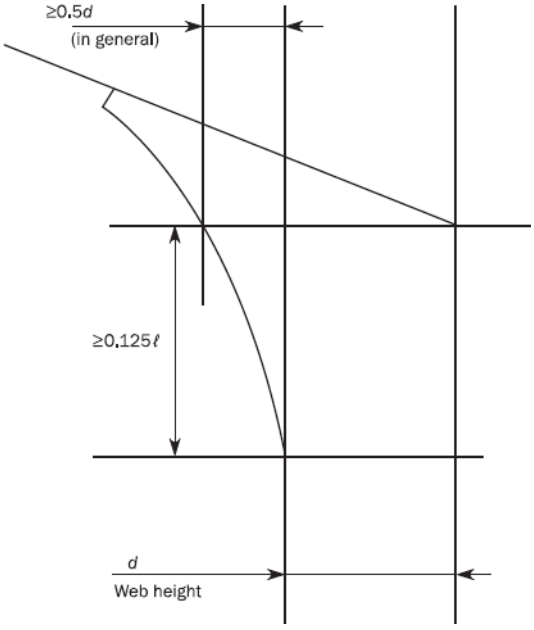


Figure 3 Dimensions of lower and upper bracket

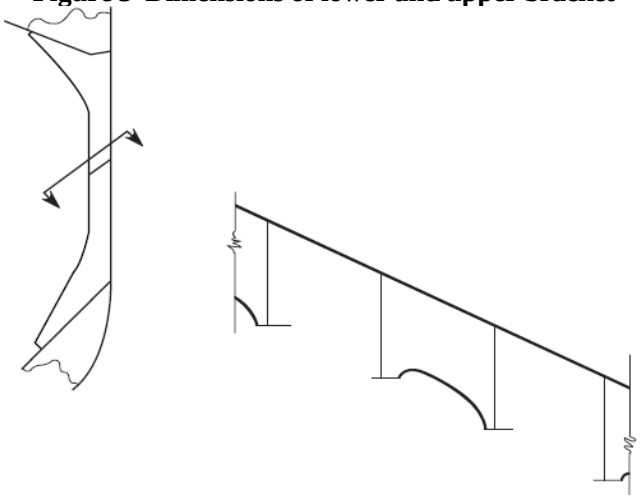


Figure 4 Tripping brackets to be fitted in way of foremost hold

3.2.6 Support structure

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Figure 5.

3.3 Deck structures

3.3.1 Web frame spacing in topside tanks

For bulk carriers with freeboard length L_{LL} less than 150 m, the spacing of web frames in topside

tanks is generally not to be greater than 6 frame spaces.

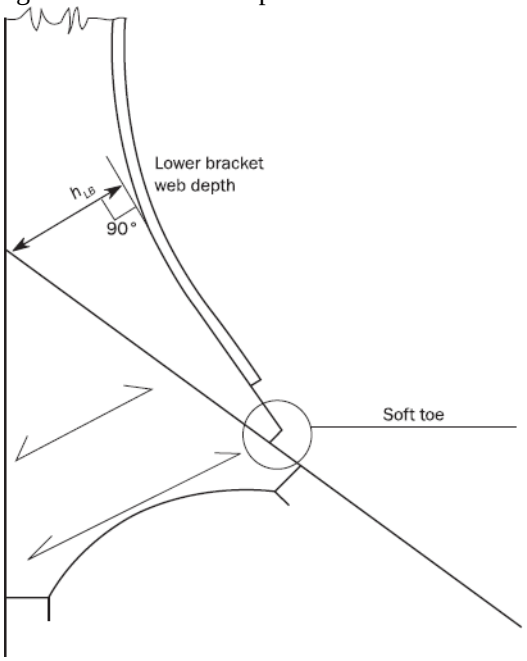


Figure 5 Example of support structure for lower end

3.3.2 Cross deck between hatches of bulk carriers

Inside the line of openings, where a transversely framed structure is adopted for the cross deck structures, hatch end beams and cross deck beams are to be adequately supported by girders and extended outward to the second longitudinal from the hatch side girders towards the deck side. Where the extension of girders outward is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal and checks of the structure are to be performed in compliance with the requirements in Pt 1, Ch 7 or by means deemed appropriate by the Society.

The transverse primary members supporting the cross deck are to be supported by side or topside tank primary supporting members.

Smooth connection of the strength deck at side with the transversely framed cross deck is to be ensured by a plate of intermediate thickness.

ISC 3.3.2a The structural strength is to be checked in compliance with the requirements in Chapter 7 of PART9-1.

3.3.3 Topside tank structures

The topside tank sloping plates are to be longitudinally framed.

Topside tank structures, where fitted, are to extend as far as possible within the machinery space and are to be adequately tapered.

Where a double side primary supporting member is fitted outside the plane of the topside tank web frame, special attention is to be paid to structural continuity.

3.3.4 Openings in strength deck - Corner of hatchways

a) Within the cargo hold region

For cargo hatchways located within the cargo hold region, insert plates, the thicknesses of which are to be determined according to the formula given after, are to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is not to be less than 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

For hatchways located within the cargo hold region, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile

and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction.
- Twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in mm, from the following formula:

$t_{INS} = (0.8+0.4l/b)t_{off}$

without being taken less than t_{off} or greater than 1.6 t_{off}.

where:

l : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Pt 1, Ch 3, Sec 6, Figure 15.

b: Width, in m, of the hatchway considered, measured in the transverse direction, see Pt 1, Ch 3, Sec 6, Figure 15.

t_{off} : Offered net thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, insert plates are required. The net thickness of these insert plates is to be 60% greater than the net offered thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in Pt 1, Ch 9, Sec 6, Table 15, in which d_1, d_2, d_3 and d_4 are to be greater than the stiffener spacing.

For ships having a freeboard length L_{LL} of 150 m or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strength assessment according to Pt 1, Ch 7, including buckling check and fatigue strength assessment of hatch corners according to Pt 1, Ch 8 and Pt 1, Ch 9 respectively. For such type of ships it is recommended to arrange circular hatch corners.

b) Outside the cargo hold region
For hatchways located outside the cargo hold region, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

ISC 3.3.4a Where two or more hatchways are arranged athwartships, the corner radius is not to be less than 5% of the total width of these hatchways.

3.3.5 Protection against wire rope

Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half- round bar on the hatch side girders (i.e. upper portion of topside tank plates) or hatch end beams in cargo hold and upper portion of hatch coamings.

3.3.6 Protection of cargo hatch opening corners against mechanical damage

Specific measures are to be arranged to prevent the hatch opening corners from mechanical damage incurred by coming into direct contact with the vertical grab wire under normal operations.

Section 3 HULL LOCAL SCANTLINGS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

C_{XG}, C_{YS}, C_{YR}, C_{YG}, C_{ZP}, C_{ZR} : Load combination factors, as defined in Pt 1, Ch 4, Sec 2.

d_{shr} : Effective shear depth of the stiffener as defined in Pt 1, Ch 3, Sec 7, [1.4.3].

F_R : Resultant force, in kN, as defined in Pt 1, Ch 4, Sec 6, Table 7.

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.1].

$F_{sc\text{-}ib}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.1].

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.2].

$F_{sc\text{-}hs}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.2].

l : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

l_p : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

l_{bdg} :Effective bending span, in m, as defined in Ch 3, Sec 7, [1.1.2].

l_{SF} : Side frame span l , in m, as defined in Ch 1, Sec 2, Figure 2, not to be taken less than 0.25 D.

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2] and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2].

P_R : Resultant pressure, in kN/m^2, as defined in Pt 1, Ch 4, Sec 6, Table 7.

s_{cw} : Plate width, in mm, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is greater,see Pt 1, Ch 3, Sec 6, Figure 21.

s_{cg} : Half pitch, in mm, of the corrugation flange as defined in Pt 1, Ch 3, Sec 6, Figure 21.

1 CARGO HOLD SIDE FRAMES OF SINGLE SIDE BULK CARRIERS

1.1 Strength criteria

1.1.1 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, in the mid-span area of side frames subjected to lateral pressure are not to be taken less than:

$$Z = 1.125\alpha_m \frac{PSl_{SF}^2}{f_{bdg}C_sR_{eH}}$$

$$A_{shr} = 5.0\alpha_S \frac{PSl_{SF}}{C_t\tau_{eH}}\left(\frac{l_{SF}-2l_B}{l_{SF}}\right)10^{-3}$$

where:

α_m : Coefficient taken as:

α_m = 0.42 for BC-A ships.

α_m = 0.36 for other ships.

f_{bdg} : Bending coefficient taken as 10.

C_s : Permissible bending stress coefficient for the design load set being considered taken as:

C_s = 0.75 for acceptance criteria set AC-S.

C_s = 0.90 for acceptance criteria set AC-SD.

α_S : Coefficient taken as:

α_S = 1.1 for side frames of empty holds in alternate condition of BC-A ships.

α_S = 1.0 for other side frames.

l_B : Lower bracket length, in m, as defined in Figure 1.

P : Design pressures, in kN/m^2, for design load sets as defined in Pt 1, Ch 6, Sec 2, Table 1,

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

C_t = 0.75 for acceptance criteria set AC-S.

C_t = 0.90 for acceptance criteria set AC-SD.

1.1.2 Side frames in ballast holds

In addition to [1.1.1], for side frames in cargo holds designed to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, all along the span are to be in accordance with Pt1, Ch 6, Sec 5 where the span of the side frame is l as defined in Pt 1, Ch 3, Sec 7, [1.1] with consideration to brackets at ends.

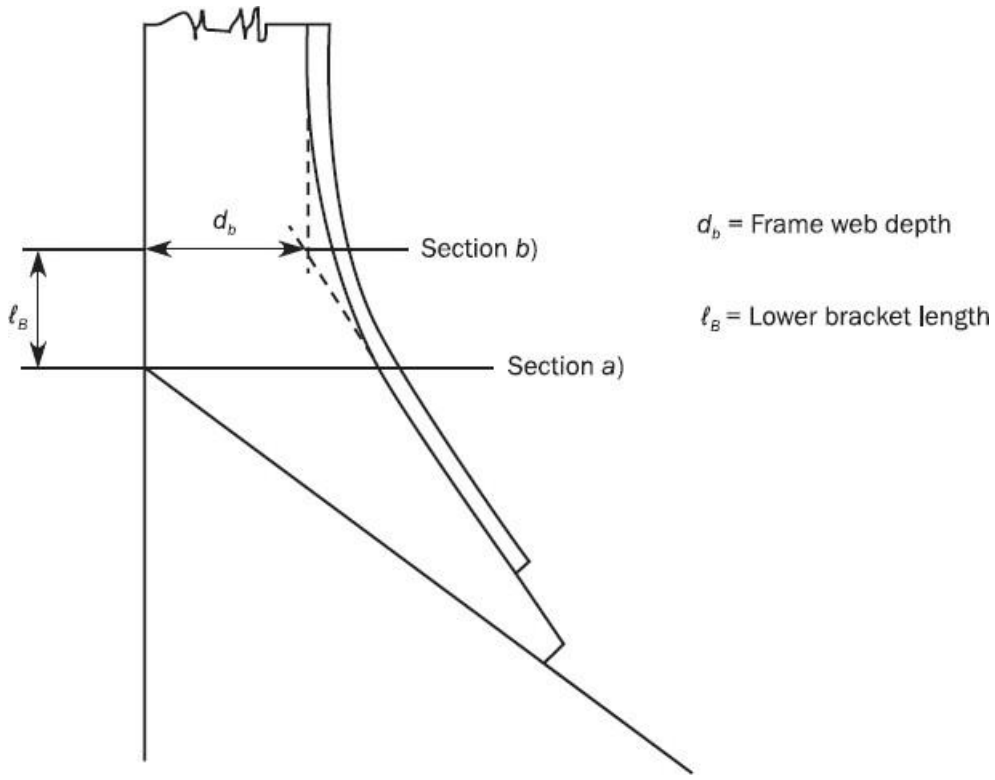


Figure 1 Side frame lower bracket length

1.1.3 Additional strength requirements

The net moment of inertia I, in cm^4, of the three side frames located immediately abaft the collision bulkhead is not to be taken less than:

$$I = 0.18\frac{Pl_{SF}^4}{n}$$

where:

n : Frame number of considered side frame counted from the collision bulkhead to the frame in question, taken equal to 1, 2 or 3.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

1.2 Lower bracket of side frame

1.2.1

At the level of the lower bracket as shown in Ch 1, Sec 2, Figure 2, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the required net section modulus Z, in cm^3,for the frame mid-span area obtained from [1.1.1].

1.2.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, at the level of the lower bracket is not to be taken less than twice the greater of the required net section moduli given in [1.1.1] and [1.1.2].

1.2.3

The net thickness t_{LB}, in mm, of the lower bracket is not to be taken less than:

$t_{LB} = t_w + 1.5$

where t_w is the net thickness of the side frame web, in mm.

1.2.4

The net thickness t_{LB} of the lower bracket is to comply with the following formula:

- For symmetrically flanged frames:
$$\frac{h_{LB}}{t_{LB}} \leq 87\sqrt{k}$$
- For asymmetrically flanged frames:
$$\frac{h_{LB}}{t_{LB}} \leq 73\sqrt{k}$$

The web depth h_{LB} of lower bracket is to be measured from the intersection between the hopper tank sloping plating and the side shell plate, perpendicularly to the face plate of the lower bracket as shown in Ch 1, Sec 2, Figure 5.

For the three side frames located immediately abaft the collision bulkhead, where the frames are strengthened in accordance with [1.1.3] and the offered t_{LB} is greater than 1.73 t_w, the t_{LB} applied in [1.2.4] may be taken as t'_{LB} given by:

$t'_{LB} = (t^2_{LB} t_W)^{1/3}$

where t_w is the net thickness of the side frame web, in mm, corresponding to A_{shr} determined in accordance to [1.1.1]

1.3 Upper bracket of side frame

1.3.1

At the level of the upper bracket as shown in Ch 1, Sec 2, Figure 2 the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the net section modulus Z required for the frame mid-span area obtained from [1.1.1].

1.3.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, at the level of the upper bracket is not to be taken less than twice the greater of the required net sections modulus obtained from [1.1.1] and [1.1.2].

The net thickness t_{UB} of the upper bracket, in mm, is not to be less than the net thickness of the side frame web.

1.4 Provided support at upper and lower connections of side frames

1.4.1 Net section modulus

The net section modulus of the:

- Side shell and hopper tank longitudinals supporting the lower connecting brackets.
- Side shell and topside tank longitudinals supporting the upper connecting brackets.

is to comply with the following formula:

$$\sum_n Z_{pli} d_i \geq \alpha_T \frac{P l_{SF}^2 l_1^2}{16 R_{eH}}$$

where:

n : Number of the longitudinal stiffeners on the side shell and hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

$Z_{pl\,i}$: Net plastic section modulus, in cm^3, of the i-th longitudinal stiffener on the side shell or hopper /topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

d_i : Distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper/topside tank.

l_1 : Spacing, in m, of transverse supporting webs in hopper/topside tank, as applicable.

R_{eH} : Lowest value of specified yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper/topside tanks that support the lower/upper end connecting bracket of the side frame.

α_T : Coefficient taken as:

α_T =150 for the longitudinal stiffeners supporting the lower connecting brackets.

α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets.

1.4.2 Net connection area of brackets

The net connection area of the lower or upper connecting bracket to the supporting longitudinal stiffener is to comply with the following formula:

$$\sum_i A_i d_i R_{eH,bkt-i} \geq 0.02 \alpha_T P s l_{SF}^2 10^{-3}$$

where:

A_i : The offered net connection area of the bracket connecting with the *i*-th longitudinal stiffener, in cm^2.

A_i , α_T : As defined in [1.4.1].

$R_{eH,bkt-i}$: The specified minimum yield stress of the bracket connecting with the *i*-th longitudinal stiffener, in N/mm^2.

s : The space of the side frame, in mm.

2 STRUCTURE LOADED BY STEEL COILS ON WOODEN DUNNAGE

2.1 General

2.1.1

The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with [2.3.1] and [2.4.1] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, hopper tank top and inner hull for ships intended to carry steel coils are to comply with [2.3.2] and [2.4.2] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

Standard terminology and means for securing of steel coils is described in Figure 2.

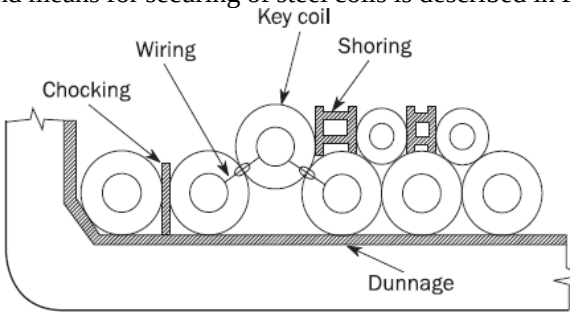


Figure 2 Inner bottom loaded by steel coils

2.2 Load application

2.2.1 Design load sets

The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1. Radius of gyration, k_r, and metacentric height, *GM*, are to be in accordance with Pt 1, Ch 4, Sec 3, Table 2 for the considered loading condition specified in the design load set. The design load sets for steel coil loading is given in Table 1.

Design load sets **Table 1**

Item	Design load set	Load component	Draught	Design load	Loading condition
Inner bottom, hopper sloping plate and inner hull	BC-9	$F_{sc\text{-}ib\text{-}s}$ or $F_{sc\text{-}hs\text{-}s}$	T_{SC}	S	Steel Coil condition
Inner bottom, hopper sloping plate and inner hull	BC-10	$F_{sc\text{-}ib}$ or $F_{sc\text{-}hs}$	T_{SC}	S+D	Steel Coil condition

2.3 Inner bottom

2.3.1 Inner bottom plating

The net thickness *t*, in mm, of plating of longitudinally framed inner bottom is not to be taken less than:

$$t = K_1 \sqrt{\frac{F_{sc-ib-s} \times 10^3}{C_a R_{eH}}}$$ for design load set BC-9

$$t = K_1\sqrt{\frac{F_{sc-ib}\times 10^3}{C_a R_{eH}}}$$ for design load set BC-10

where:

K_1 : Coefficient taken as:

$$K_1 = \sqrt{\frac{1.7\frac{s}{1000}lK_2 - 0.73(\frac{s}{1000})^2 K_2^2 - (l-l_{lp})^2}{2l_{lp}(2\frac{s}{1000}+2lK_2)}}$$

K_2 : Coefficient taken as:

$$K_2 = -\frac{s}{1000l} + \sqrt{(\frac{s}{1000l})^2 + 1.37(\frac{1000l}{s})^2(1-\frac{l_{lp}}{l})^2 + 2.33}$$

C_a : Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 4, [1.1.1].

2.3.2 Stiffeners of inner bottom plating

The net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, of single span stiffeners located on inner bottom plating are not to be taken less than:

$$Z = K_3\frac{F_{sc-ib-s}}{8C_s R_{eH}}10^3 \text{ and } t_w = \frac{0.5F_{sc-ib-s}}{d_{shr}C_t\tau_{eH}}\times 10^3$$ for design load set BC-9.

$$Z = K_3\frac{F_{sc-ib}}{8C_s R_{eH}}10^3 \text{ and } t_w = \frac{0.5F_{sc-ib}}{d_{shr}C_t\tau_{eH}}\times 10^3$$ for design load set BC-10

where:

K_3 : Coefficient as defined in Table 2.

$K_3 = 2l_{bdg}/3$, when $n_2 > 10$.

C_s : Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 5, [1.1.2].

C_t: Permissible shear stress coefficient for the design load set being considered, to be taken as:

$C_t = 0.85$ for acceptance criteria set AC-S.

$C_t = 1.00$ for acceptance criteria set AC-SD.

n_2: Number of load points per EPP of the inner bottom, see Pt 1, Ch 4, Sec 6, [4.1.3].

Coefficient K_3 **Table 2**

n_2	1	2	3	4	5
K_3	l_{bdg}	$l_{bdg}-\frac{l_{lp}^2}{l_{bdg}}$	$l_{bdg}-\frac{2l_{lp}^2}{3l_{bdg}}$	$l_{bdg}-\frac{5l_{lp}^2}{9l_{bdg}}$	$l_{bdg}-\frac{l_{lp}^2}{2l_{bdg}}$

n_2	6	7	8	9	10
K_3	$l_{bdg}-\frac{7l_{lp}^2}{15l_{bdg}}$	$l_{bdg}-\frac{4l_{lp}^2}{9l_{bdg}}$	$l_{bdg}-\frac{3l_{lp}^2}{7l_{bdg}}$	$l_{bdg}-\frac{5l_{lp}^2}{12l_{bdg}}$	$l_{bdg}-\frac{11l_{lp}^2}{27l_{bdg}}$

2.4 Hopper tank and inner hull

2.4.1 Hopper sloping plating and inner hull plating

The net thickness t, in mm, of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be taken less than:

$$t = K_1\sqrt{\frac{F_{sc-hs-s}}{C_a R_{eH}}10^3}$$ applicable for design load set BC-9.

$$t = K_1\sqrt{\frac{F_{sc-hs}}{C_a R_{eH}}10^3}$$ applicable for design load set BC-10.

where:

K_1 : Coefficient as defined in [2.3.1].

C_a : As defined in [2.3.1].

2.4.2 Stiffeners of hopper sloping plating and inner hull plating

The net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are not to be taken less th

$$Z = K_3 \frac{F_{sc-hb-s}}{8C_s R_{eH}} 10^3 \text{ and } t_w = \frac{0.5F_{sc-hb-s}}{d_{shr} C_t \tau_{eH}} \times 10^3, \text{ applicable for design load set BC-9.}$$

$$Z = K_3 \frac{F_{sc-hb}}{8C_s R_{eH}} 10^3 \text{ and } t_w = \frac{0.5F_{sc-hb}}{d_{shr} C_t \tau_{eH}} \times 10^3, \text{ applicable for design load set BC-10.}$$

where:

K_3 : Coefficient as defined in Table 2.

$K_3 = 2l_{bdg}/3$, when $n_2 > 10$.

C_s, C_t : As defined in [2.3.2].

3 TRANSVERSE VERTICALLY CORRUGATED WATERTIGHT BULKHEADS SEPARATING CARGO HOLDS IN FLOODED CONDITION

3.1 Net thickness of corrugation

3.1.1 Cold formed corrugation

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.1].

3.1.2 Built-up corrugation

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness t_N, in mm, of the narrower plating is not to be taken less than:

$$t_N = 14.9 \cdot 10^{-3} s_N \sqrt{\frac{1.05P_R}{R_{eH}}}$$

s_N : Plate width, in mm, of the narrower plating.

The net thickness t_W, in mm, of the wider plating is not to be taken less than the greater of the following formulae:

$$t_W = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

$$t_W = \sqrt{\frac{4.62 s_{CW}^2 P_R}{R_{eH} 10^4} - t_{NO}^2}$$

where:

t_{NO} : Net offered thickness of the narrower plating, in mm, not to be taken greater than:

$$t_{NO} = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.2].

3.1.3 Lower part of corrugation

The net thickness of the lower part of corrugations is to be maintained for a distance of not less than $0.15l_C$ measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations l_C, in m, is to be taken as given in Pt 1, Ch 3, Sec 6, [10.4.5].

3.1.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than 0.3 l_C from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to com- ply with the requirements in [3.2.1] and Pt 1, Ch 6, Sec 4, [1.2].

3.2 Bending, shear and buckling check

3.2.1 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}}10^3$$

where:

M : Bending moment in a corrugation, in kNm, taken as:

$$M = \frac{F_R l_C}{8}$$

F_R : Resultant force, in kN, given in Pt 1, Ch 4, Sec 6, [3.1.7].

l_C : Span of the corrugations, in m, as given in Pt 1, Ch 3, Sec 6, [10.4.5].

W_{LE} : Net section modulus, in cm3, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [3.3], not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Qh_G 10^3 - 0.5h_G^2 s_C p_R}{R_{eH}}$$

W_G : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [3.3].

Q : Shear force, in kN, at the lower end of a corrugation, to be taken as:
$Q = 0.8\, F_R$

h_G : Height, in m, of shedders or gusset plates, as applicable as shown in Figure 4 to Figure 6.

P_R : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Pt 1, Ch 4, Sec 6, [3.1.7].

W_M : Net section modulus, in cm3, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [3.3] without being taken greater than 1.15 W_{LE}.

τ : Shear stress, in N/mm^2, in the corrugation to be taken as:

$$\tau = 10\frac{Q}{A_{shr}}$$

A_{shr} : Net shear area, in cm^2, of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by $\sin\phi$.

ϕ : Angle between the web and the flange, see Pt 1, Ch 3, Sec 6, Figure 21.

The net section modulus of the corrugations in the upper part of the bulkhead, as defined in Figure 3, is not to be taken less than 75% of that of the middle part complying with this requirement and Pt 1, Ch 6, Sec 4, [1.2], corrected for different minimum yield stresses.

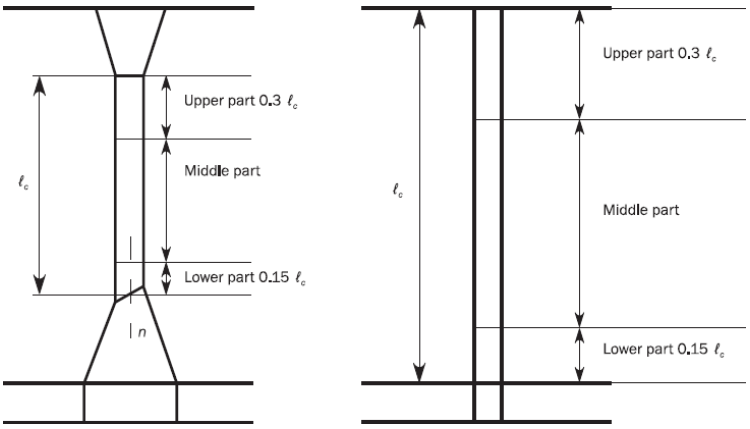


Figure 3 Parts of corrugation

3.2.2 Shear buckling check of the bulkhead corrugation webs

The shear stress τ , calculated according to [3.2.1], is to comply with the following formula:

$\tau \leq \tau_C$

where:

τ_C : Critical shear buckling stress, in N/mm^2, to be taken as:

$$\tau \leqslant \tau_C \text{ for } \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \text{ for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress, in N/mm^2, to be taken as:

$$\tau_E = 0.9 k_t E \left(\frac{t_w}{b_{w-cg}}\right)^2$$

k_t : Coefficient, to be taken equal to 6.34.

t_w : Net thickness, in mm, of the corrugation webs.

b_{w-cg} : Width, in mm, of the corrugation webs as shown in Pt 1, Ch 3, Sec 6, Figure 21.

3.3 Net section modulus of the corrugations

3.3.1 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} not larger than the following formula:

$b_{eff} = C_E b_{f-cg}$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for } \beta > 1.25$$

$C_E = 1.0$ for $\beta \leq 1.25$

β : Coefficient to be taken equal to:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

b_{f-cg} : Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

t_f : Net flange thickness, in mm.

3.3.2 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in [3.3.5], if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

3.3.3 Effective shedder plates

Provided that effective shedder plates are fitted as shown in Figure 4, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 4), the net area, in cm^2, of flange plates may be increased by I_{SH} to be taken as:

$I_{SH} = 2.5 \cdot 10^{-3} b_{f-cg} \sqrt{t_f t_{SH}}$ without being taken greater than $2.5 b_{f\text{-}cg}\, t_f\, 10^{-3}$

where:

$b_{f\text{-}cg}$: Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

t_{SH} : Net shedder plate thickness, in mm.

t_f : Net flange thickness, in mm.

Effective shedder plates are those which:

- are not knuckled,
- are welded to the corrugations and the lower stool top plate according to Pt 1, Ch 12,
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating,
- have net thickness not less than 75% of the net required for the corrugation flanges,
- have material properties not less than those required for the flanges.

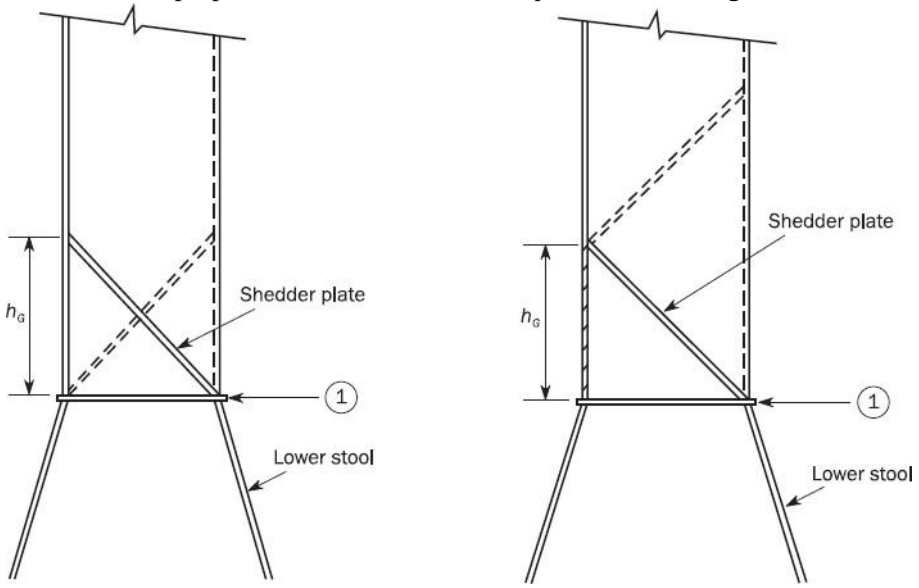


Figure 4 Symmetrical and unsymmetrical shedder plates

3.3.4 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 5 and Figure 6), the net area, in cm^2, of flange plates may be increased by I_G to be taken as:

$I_G = 7\, h_G\, t_f$

h_G : Height, in m, of gusset plates as shown in Figure 5 and Figure 6 but not to be taken greater than:

$$\frac{10 S_{GU}}{7}$$

S_{GU} : Width, in m, of gusset plates.

t_f : Net flange thickness, in mm.

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [3.3.3],
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to Pt1, Ch12, Sec 3, [2.4.6],
- have net thickness and material properties not less than those net required for the flanges.

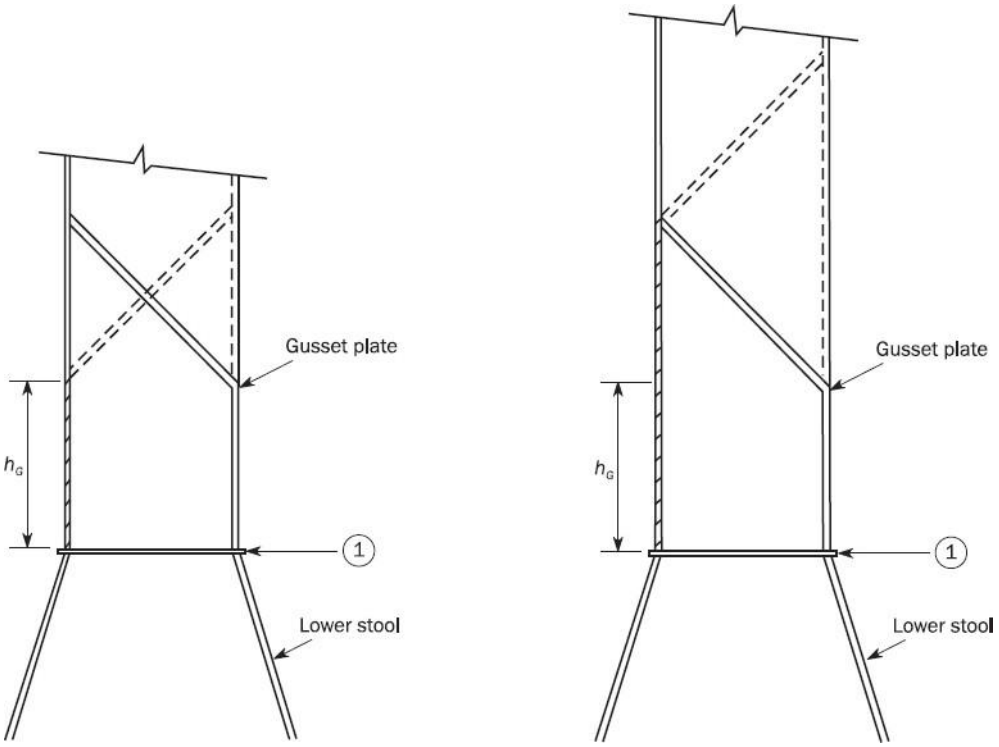


Figure 5 Symmetrical and unsymmetrical gusset / shedder plates

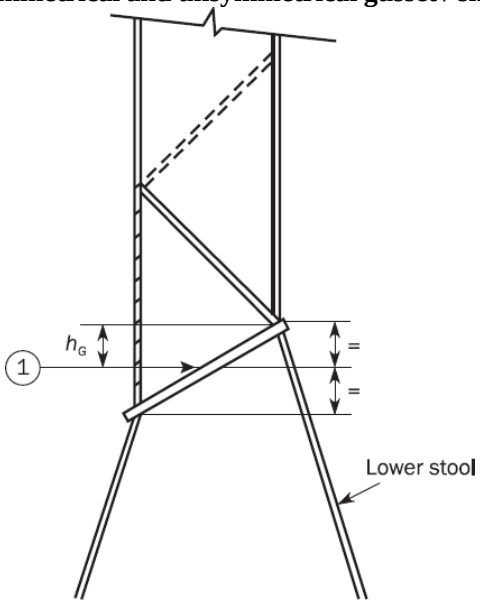


Figure 6 Asymmetrical gusset / shedder plates

3.3.5 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45ºwith the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45º, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0ºand 100% efficient for 45º.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in [3.3.4] above. No credit may be given to shedder plates only.

4 ALLOWABLE HOLD LOADING FOR BC-A & BC-B SHIPS IN FLOODED CONDITIONS

4.1 Evaluation of double bottom capacity and allowable hold loading

4.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in Figure 7. The shear strength of floors is to be calculated according to [4.1.2].
- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to [4.1.3].

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in Pt 1, Ch 7, as applicable.

4.1.2 Floor shear strength

The floor shear strength, in kN, is to be taken as given in the following formulae:

- In way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f1} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank.

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank).

τ_A : Allowable shear stress, in N/mm^2, to be taken as the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{(s/t)^{0.8}} \text{ and } \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, τ_A is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

t : Floor web net thickness, in mm.

s : Spacing, in m, of stiffening members of the panel considered.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

ISC 4.1.2a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η_2 may be taken as 1.1.

4.1.3 Girder shear strength

The girder shear strength, in kN, is to be taken as given in the following formulae:

- In way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

A_g : Net sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted).

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted.

τ_A : Allowable shear stress, in N/mm^2, as defined in [4.1.2] where t is the girder web net thickness.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by- case basis.

ISC 4.1.3a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η2 may be taken as 1.1.

4.1.4 Allowable hold loading

The allowable hold loading, in t, is to be taken as:

$$W = \rho_C V \frac{1}{F}$$

where:

ρ_C : Density of the dry bulk cargo, in t/m^3, as defined Pt 1, Ch 4, Sec 6, [2.3.3].

V : Volume, in m^3, occupied by the cargo up to the level h_B.

F : Coefficient to be taken as:

F = 1.1 in general.

F = 1.05 for steel mill products.

h_B : Level of cargo, in m, to be taken as:

$$h_B = \frac{P}{\rho_C g}$$

P : Pressure, in kN/m^2, to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 + \frac{\rho}{\rho_C}(perm - 1)}$$

$$P = Z + \rho g(z_F - 0.1D_1 - h_F perm)$$

- For steel mill products:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 - \frac{\rho}{\rho_{st}}}$$

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

h_F : Inner bottom flooded height, in m, measured vertically with the ship in the upright position, from the inner bottom to the flooded level z_F.

z_F : Flooded level, in m, as defined in Pt 1, Ch 4, Sec 6, [3.2.3].

perm : Permeability of cargo, which need not be taken greater than 0.3.

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7.85.

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,H}$: Area, in m^2, taken as:

$$A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$$

C_E : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the shear strength S_{f1} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,E}$: Area, in m^2, taken as:

$$A_{DB,E} = \sum_{i=1}^{n} S_i (B_{DB} - s)$$

n : Number of floors between stools or transverse bulkheads, if no stool is fitted.

S_i : Space of i-th floor, in m.

$B_{DB,i}$: Length, in m, to be taken equal to:

$B_{DB,i} = B_{DB-s}$ for floors for which $S_{f1} < S_{f2}$.

$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geqslant S_{f2}$.

B_{DB} : Breadth, in m, of double bottom between the hopper tanks as shown in Figure 8.

$B_{DB,h}$: Distance, in m, between the two openings considered as shown in Figure 8.

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

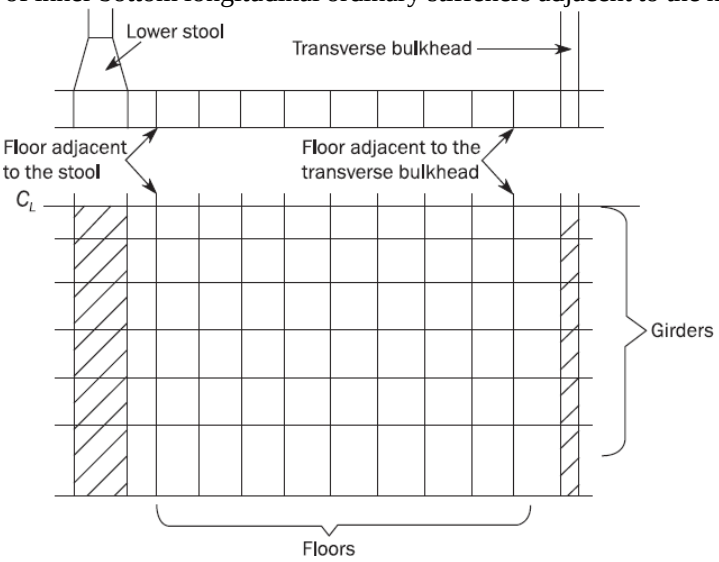


Figure 7 Double bottom structure

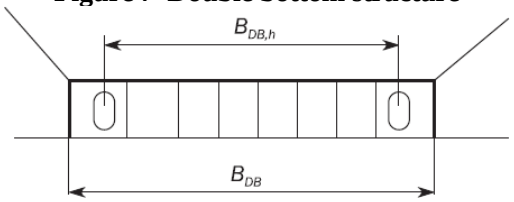


Figure 8 Dimensions B_{DB} and $B_{DB,h}$

Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS L<150M

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

l_{DB} : Length of the double bottom within hold under consideration, in m. Where stools are provided at transverse bulkheads, l_{DB} may be taken as the distance between the toes.

B_{DB} : Distance between the toes of hopper tanks at centre of B_{DB} within hold under consideration, in m.

x_c : X coordinate, in m, of the centre of double bottom structure under consideration with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

x, y, z : X, Y and Z coordinates, in m, of the evaluation point with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

ϕ : Depth of the openings in parallel to web depth of primary support members, in m.

α : The greater of a or S_1, in m.

1 GENERAL

1.1 Application

1.1.1

Unless otherwise defined, the requirements of this section define the strength criteria applicable to bulk carriers with freeboard length L_{LL} of less than 150 m.

2 STRUTS CONNECTING STIFFENERS

2.1 Scantling requirements

2.1.1 Net sectional area and moment of inertia

The net sectional area A_{SR}, in cm^2, and the net moment of inertia I_{SR} about the main axes, in cm^4, of struts connecting stiffeners are not to be less than the values obtained from the following formulae:

$$A_{SR} = \frac{P_{SR} s l}{20000}$$

$$I_{SR} = \frac{0.75 s l (P_{SR1} + P_{SR2}) A_{ASR} l_{SR}^2}{47200 A_{ASR} - s l (P_{SR1} + P_{SR2})}$$

where:

P_{SR} : Pressure to be taken as the greater of the following values, in kN/m^2:

P_{SR}=0.5(P_{SR1}+ P_{SR2}）

P_{SR}= P_{SR3}

P_{SR1} : External pressure in way of the strut, in kN/m^2, acting on one side, outside the compartment in which the strut is located.

P_{SR2} : External pressure in way of the strut, in kN/m^2, acting on the opposite side, outside the compartment in which the strut is located.

P_{SR3}: Internal pressure at mid-span of the strut, in kN/m2, in the compartment in which the strut is located.

s : Spacing, in mm, of stiffeners, measured at mid-span along the chord.

l : Span, in m, of stiffeners connected by the strut defined in Pt 1, Ch 3, Sec 7, [1.1.5].

l_{SR} : Length of the strut, in m.

A_{ASR} : Actual net sectional area of the strut, in cm^2.

3 TRANSVERSE CORRUGATED BULKHEADS OF BALLAST HOLDS

3.1 Plate thickness

3.1.1

The net thickness of web and flange plating is not to be less than the values obtained in Pt 1, Ch 6, Sec 3, [1.1.1] and Pt 1, Ch 6, Sec 4, [1.2].

3.2 Net section modulus

3.2.1

The net section modulus Z, in cm^3, of corrugated bulkhead of ballast holds, subjected to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K \frac{P s_{cg} l^2}{f_{bdg} C_s R_Y}$$

where:

K : Coefficient given in Table 1 and Table 2, according to the type of end connection. When $d_H < 2.5\ d_0$, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

P : Design pressure for the design load set as defined in Pt 1, Ch 6, Sec 2, Table 1 and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2], in kN/m^2.

s_{cg} : Half pitch length, in mm, of the corrugation, as defined in Pt 1, Ch 3, Sec 6, Figure 21.

l : Length, in m, between the supports, as indicated in Figure 1.

C_s : Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

f_{bdg}: Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

The effective width of the corrugation flange in compression is to be considered according to Ch 1, Sec 3, [3.3.1] when the net section modulus of corrugated bulkhead is calculated.

Values of K, in case $d_H \geqslant 2.5\ d_0$ **Table 1**

Upper end support	
Welded directly to deck	Welded to stool efficiently supported by ship structure
1.00	0.83

Values of K, in case $d_H < 2.5\ d_0$ **Table 2**

Section modulus of	Upper end support	
	Connected to deck	Connected to stool
Corrugated bulkhead	0.71	0.65
Stool at bottom	1.25	1.13

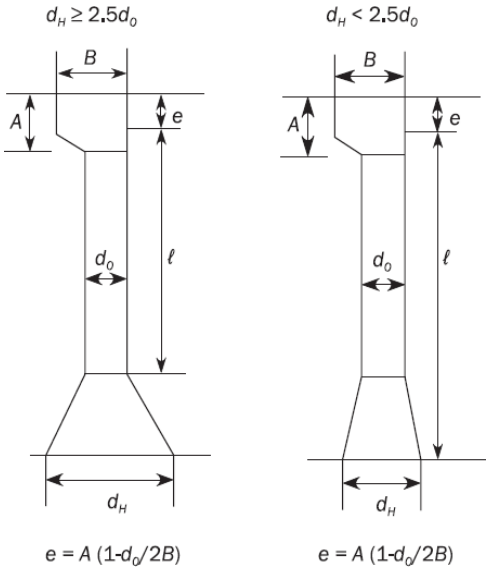


Figure 1 Measurement of l

4 PRIMARY SUPPORTING MEMBERS

4.1 Application

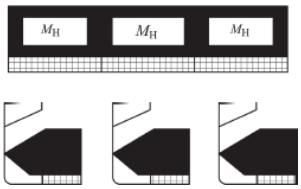
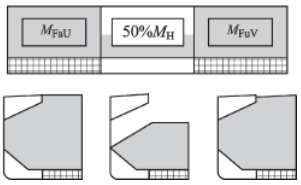
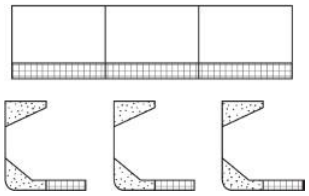
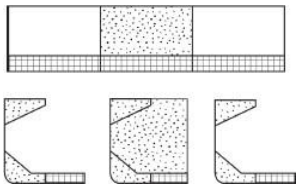
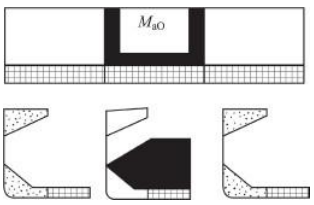
4.1.1

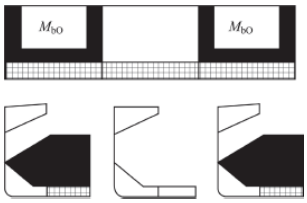
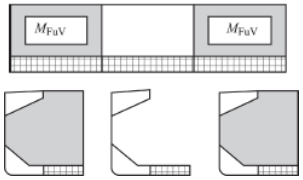
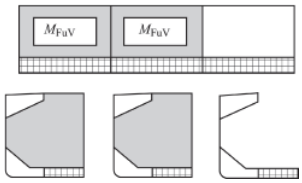
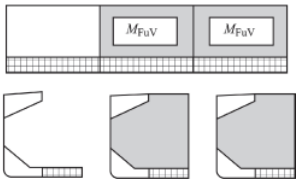
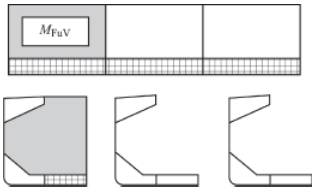
The requirements of this section apply to the strength check of primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a freeboard length L_{LL} less than 150 m.

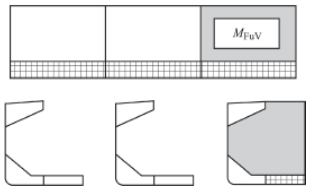
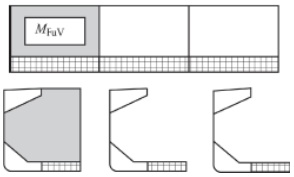
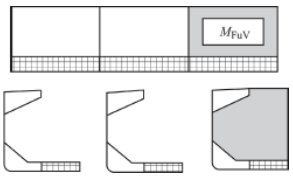
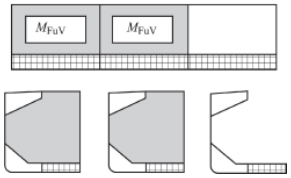
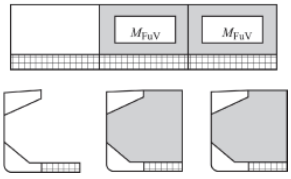
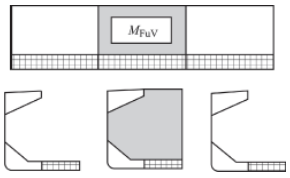
4.1.2
As an alternative to [4.1.1], the strength check may be verified by direct strength assessment deemed as appropriate by the Society.

ISC 4.1.2a As an alternative to 4.1.1, the scantlings of primary supporting members within the midship cargo hold region may be verified by direct strength assessment according to the requirements in Chapter 7 of PART 9-1 and the load combinations as given in Table ISC 4.1.2a.

FE Load combinations Table **ISC 4.1.2a**

No	Description	Loading pattern	Draught	Permissible still water bending moment (%)	Permissible still Water shear force (%)	Dynamic load case
Seagoing conditions						
1	Full load		T_{SC}	50% sag.	100%	BSP-1P, BSP-1S OST-1P,OST-1S
2	Slack load		T_{SC}	0%	100%	BSP-1P,BSP-1S
3	Normal ballast		T_{BAL-N}	100% hog.	100%	FSM-2,BSR-1P, BSR-1S, OST-2P,OST-2S
4	Heavy ballast (if any)		T_{BAL-H}	0%	100% Max SFLC	FSM-2, HSM-2
					100%	BSR-1P,BSR-1S
				100% sag.	100% Max SFLC	HSM-1
					100% Max SFLC	HSM-1
					100%	BSR-1P,BSR-1S
5	Alternate Load loaded hold (if any)		T_{SC}	100% hog.	100% Max SFLC	FSM-2, HSM-2
					100%	OST-2P,OST-2S
				0%	100% Max SFLC	FSM-1 HSM-1
					100% Max SFLC	FSM-1 HSM-1
					100%	BSP-1P, BSP-1S OST-1P,OST-1S

No	Description	Loading pattern	Draught	Permissible still water bending moment (%)	Permissible still Water shear force (%)	Dynamic load case
6	Alternate Load empty hold (if any)		T_{SC}	100% hog.	100% Max SFLC	FSM-2 HSM-2
					100%	OST-2P,OST-2S
				0%	100% Max SFLC	FSM-1 HSM-1
					100% Max SFLC	FSM-1 HSM-1
					100%	BSP-1P, BSP-1S OST-1P,OST-1S
7	Multiport (if any)		$0.83T_{SC}$	100% hog.	100% Max SFLC	FSM-2 HSM-2
					100% Max SFLC	FSM-2 HSM-2
					100%	OST-2P,OST-2S
				100% sag.	100% Max SFLC	HSM-1
					100%	BSP-1P, BSP-1S OST-1P,OST-1S
8	Multiport (if any)		$0.67T_{SC}$	100% sag.	100%	BSP-1P,BSP-1S OST-1P,OST-1S
9	Multiport (if any)		$0.67T_{SC}$	100% sag.	100%	BSP-1P,BSP-1S OST-1P,OST-1S
10	Multiport (if any)		$0.75T_{SC}$	100% hog.	100%	FSM-2 HSM-2 BSR-1P, BSR-1S OST-2P,OST-2S
				100% sag.	100%	BSP-1P, BSP-1S BSR-1P,BSR-1S OST-1P,OST-1S

No	*Description*	*Loading pattern*	*Draught*	*Permissible still water bending moment (%)*	*Permissible still Water shear force (%)*	*Dynamic load case*
11	*Multiport (if any)*		*0.75T_{SC}*	*100% hog.*	*100%*	*FSM-2 HSM-2 BSR-1P,BSR-1S OST-2P,OST-2S*
				100% sag.	*100%*	*BSP-1P,BSP-1S BSR-1P,BSR-1S OST-1P,OST-1S*
Harbour conditions						
12	*Harbour condition*		*0.67T_{SC}*	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
13	*Harbour condition*		*0.67T_{SC}*	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
14	*Harbour condition*		*TH_1*	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
15	*Harbour condition*		*TH_1*	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
16	*Harbour condition*		*TH_2*	*100% hog.*	*100% Max SFLC*	*N/A*
					100% Max SFLC	*N/A*
				100% sag	*100% Max SFLC*	*N/A*
					100% Max SFLC	*N/A*

Other loading conditions from the Loading Manual, which are not covered in the above Table are also to be considered. In these cases, actual values of draught and hull girder static loads are to be used, and dynamic load cases corresponding to the loading patterns are to be applied. For example, while the still water bending moment corresponding to the loading pattern is positive, dynamic load cases with hogging wave bending moment are to be applied.

ISC 4.1.2b The scantlings of the primary supporting members in the midship cargo region are also to comply with the minimum thickness requirements in Section 3, Chapter 6 and the aspect ratio requirements in Section 2, Chapter 8 of PART 9-1.

4.2 Design load sets

4.2.1 Application

Design load sets as given in Table 3 are to be considered for primary supporting members on cargo hold boundaries of bulk carriers with freeboard length L_{LL} less than 150 m.

Design load sets for primary supporting members in cargo hold region Table 3

Item	Design load set	Load component	Draught	Design load	Loading condition
• Double bottom floors and girders • Stringers and transverse web frames in double side structures	WB-4 (1)	P_{in}-P_{ex}	T_{BAL-H}	S+D	Heavy ballast condition
	WB-6 (1)	P_{in}	-	S	Harbour/test condition
	BC-11	P_{in}-P_{ex}	T_{SC}	S+D	Full load condition
	BC-12	P_{in}-P_{ex}	T_{SC}	S	Harbour condition
	FD-1(2)	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2(2)	P_{in}	-	S	Flooded condition
(1) Only applicable to holds assigned as ballast hold. (2) Not applicable to holds assigned as ballast hold.					

4.2.2 Loading conditions

The severest loading conditions from the loading manual or otherwise specified by the designer are to be considered for the calculation of *Pin* in design load sets BC-11 to BC-12.

For Primary supporting member in bilge hopper tanks and topside tanks, applicable design load sets in Pt 1, Ch 6, Sec 2, Table 1 are to be considered.

4.3 Centre girders and side girders

4.3.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_1 \frac{|P|S|x - x_c|}{(d_0 - d_1)C_{t-pr}\tau_{eH}} \left\{1 - 4\left(\frac{y}{B_{DB}}\right)^2\right\}$$

where $|x - x_c|$ is less than $0.25 l_{DB}$, $|x - x_c|$ is to be taken as $0.25\ l_{DB}$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 C_{t-pr}\tau_{eH}}{C_1'}}\, t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in m.

d_0 : Depth of the centre or side girder under consideration, in m.

d_1 : Depth of the opening, if any, at the point under consideration, in m.

C_1 : Coefficient given in Table 4 depending on B_{DB}/l_{DB}. For intermediate values of B_{DB}/l_{DB}, C_1 is to be obtained by linear interpolation.

a : Depth of girders at the point under consideration, in m. However, where horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or floors.

C'_1: Coefficient given in Table 5 depending on S_1/a. For intermediate values of S_1/a, C'_1 is to be

determined by linear interpolation.

H : Value obtained from the following formulae:

- Where the girder is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:

H=1.0

Coefficient C_1 **Table 4**

B_{DB}/l_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_1	0.5	0.71	0.83	0.88	0.95	0.98	1.00

Coefficient C'_1 **Table 5**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_1	64	38	25	19	15	12	10	9	8	7

4.4 Floors

4.4.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 and t_2 specified in the following according to each location:

$$t_1 = C_2 \frac{|P| SB_{DB}}{(d_0 - d_1) C_{t-pr} \tau_{eH}} \left(\frac{2|y|}{B'_{DB}}\right) \left\{1 - 2\left(\frac{x - x_c}{l_{DB}}\right)^2\right\}$$

where $|x - x_c|$ is less than $0.25 l_{DB}$, $|x - x_c|$ is to be taken as $0.25 l_{DB}$, and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 C_{t-pr} \tau_{eH}}{C'_2}} t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Spacing of solid floors, in m.

d_0 : Depth of the solid floor at the point under consideration in m.

d_1 : Depth of the opening, if any, at the point under consideration in m.

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m.

C_2 : Coefficient given in Table 6 depending on B_{DB}/l_{DB}. For intermediate values of B_{DB}/l_{DB}, C_2 is to be obtained by linear interpolation.

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or girders.

C'_2 : Coefficient given in Table 7 depending on S_1/d_0. For intermediate values of S_1/d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

Where openings with reinforcement or no opening are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$$ without being taken less than 1.0.

- Where slots with reinforcement are provided:

H = 1.0

Where openings without reinforcement are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = (1 + 0.5\frac{\phi}{d_0})\sqrt{4.0\frac{d_2}{S_1} - 1.0}$$ without being taken less than $1 + 0.5\frac{\phi}{d_0}$

- where slots with reinforcement are provided:

$$H = 1 + 0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

Coefficient C_2 **Table 6**

B_{DB}/l_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
$C2$	0.48	0.47	0.45	0.43	0.40	0.37	0.34

Coefficient C'_2 **Table 7**

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_2	64	38	25	19	15	12	10	9	8	7

4.5 Stringer of double side structure

4.5.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_3\frac{|P|S|x - x_c|}{(d_0 - d_1)C_{t-pr}\tau_{eH}}$$

where $|x - x_c|$ is under $0.25l_{DS}$, $|x - x_c|$ is to be taken as $0.25l_{DS}$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2a^2C_{t-pr}\tau_{eH}}{C'_3}}t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of l_{DS}.

S : Breadth of part supported by stringer, in m.

d_0 : Depth of stringers, in m.

d_1 : Depth of opening, if any, at the point under consideration, in m.

l_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m.

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m.

C_3 : Coefficient given in Table 8 depending on h_{DS}/l_{DS}. For intermediate values of h_{DS}/l_{DS}. C_3 is to be obtained by linear interpolation.

a :Depth of stringers at the point under consideration, in m. However, where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of transverse stiffeners or web frames.

C'_3 : Coefficient given in Table 9 depending on S_1/a. For intermediate values of S_1/a, C'_3 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the stringer is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:

H=1.0

Coefficient C_3 **Table 8**

h_{DS}/l_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Coefficient C'_3 **Table 9**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_3	64	38	25	19	15	12	10	9	8	7

4.6 Transverse web in double side structure

4.6.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_4 \frac{|P| S h_{DS}}{(d_0 - d_1) C_{t-pr} \tau_{eH}} (1 - 1.75 \frac{z - z_{BH}}{h'_{DS}})$$

where $z - z_{BH}$ is greater than $0.4h'_{DS}$, $z - z_{BH}$ is to be taken as $0.4h'_{DS}$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 C_{t-pr} \tau_{eH}}{C'_4}} t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of l_{DS}.

S : Breadth of part supported by transverses, in m.

d_0 : Depth of transverses, in m.

d_1 : Depth of opening at the point under consideration, in m.

C_4 : Coefficient given in Table 10 depending on h_{DS}/l_{DS}. For intermediate values of h_{DS}/l_{DS}, C_4 is to be obtained by linear interpolation.

z_{BH} : Z coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in Pt 1, Ch 1, Sec 4, [3.6].

h_{DS} : As defined in the requirements of [4.5.1].

h'_{DS}: Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in m.

l_{DS} : As defined in the requirements of [4.5.1].

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal stiffeners or stringers.

C'_4 : Coefficient given in Table 11 depending on S_1/a. For intermediate values of S_1/a, C'_4 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the transverse is provided with an unreinforced opening:

$$H = 1 + 0.5 \frac{\phi}{\alpha}$$

- In other cases:
  H = 1.0.

α : The greater of a or S_1 in m.

Coefficient C_4 **Table 10**

h_{DS}/l_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Coefficient C'_4 **Table 11**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over

C'_4	64	38	25	19	15	12	10	9	8	7

4.7 Primary supporting member in bilge hopper tanks and topside tanks

4.7.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by- case basis.

ISC 4.7.1a The requirements of this paragraph apply to the primary supporting members considered as clamped at both ends. For boundary conditions deviated significantly from the above, strength check is to be performed in accordance with ISC 4.1.2a.

4.7.2 Net section modulus, net shear sectional area and web thickness

The net section modulus Z, in cm^3, the net shear sectional area A_{shr}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P| Sl_{bdg}^2}{f_{bdg} C_{s-pr} R_{eH}} 10^3$$

$$A_{shr} = \frac{5|P| Sl_{shr}}{C_{t-pr} \tau_{eH}}$$

$$t_w = 1.75 \sqrt[3]{\frac{h_w C_{t-pr} \tau_{eH}}{10^4 C_5} A_{shr}}$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at the mid-point of span l of a web frame located midway between transverse bulkheads of holds.

S : Spacing of primary supporting members, in m.

l_{bdg} : Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.6].

l_{shr} : Effective shear span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.7].

f_{bdg} : Bending moment factor:

- For continuous primary supporting members and where end connections are fitted consistent with idealisation of the primary supporting members as having as fixed ends and is not to be taken higher than:
  $f_{bdg} = 10$
- For primary supporting members with reduced end fixity, the yield check is to be considered on a case-by-case basis.

C_{s-pr} : Permissible bending stress coefficient for primary supporting members taken equal to:
$C_{s-pr} = 0.70$ for AC-S.
$C_{s-pr} = 0.85$ for AC-SD.

h_w : Web height, in mm.

C_5 : Coefficient defined in Table 12 according to s_1 and d_0. For intermediate values of s_1 / d_0, coefficient C_5 is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m.

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m.

ISC 4.7.2a For the primary supporting members with reduced end fixity, strength check is to be performed in accordance with ISC 4.1.2a.

Coefficient C_5 **Table 12**

s_1 / d_0	0.3 and less	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

Section 5 CARGO HATCH COVERS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

P_S : Still water pressure, in kN/m^2, as defined in [4.1].

P_W : Wave pressure, in kN/m^2, as defined in [4.1].

P_C : Pressure acting on the hatch coaming, in kN/m^2, as defined in [6.2].

F_S, F_W : Coefficients taken equal to:

F_S = 0 and F_W = 0.9 for ballast water loads on hatch covers of the ballast hold.

F_S = 1.0 and F_W = 1.0 in other cases.

b_p : Effective breadth, in mm, of the plating attached to the stiffener, as defined in [3].

A_{shr} : Net shear sectional area, in cm2, of the stiffener or primary supporting member.

f_{bc} : Boundary coefficient for stiffeners and primary supporting members, taken equal to:

f_{bc} = 8, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end.

f_{bc} = 12, in the case of stiffeners and primary supporting members clamped at both ends.

t_c : Total corrosion addition, in mm, as defined in [1.4].

σ_a,τ_a : Allowable stresses, in N/mm2, as defined in [1.5].

1 GENERAL

1.1 Application

1.1.1

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, as defined in Pt 1, Ch 1, Sec 4, [3.2].

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

ISC 1.2.1a Materials used for the construction of top plating, bottom plating and primary supporting members of steel hatch covers are to comply with the material grade requirements for class I as specified in Table 7 of 2.3 in Section 1, Chapter 3 of PART 9-1.

1.2.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

ISC 1.2.2a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of ISC.

1.3 Net scantlings

1.3.1

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Pt 1, Ch 3, Sec 2.

The corrosion additions are given in [1.4].

1.4 Corrosion additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Table 1.

The corrosion addition for hatch coamings and coaming stays is defined according to Pt 1, Ch 3, Sec 3.

Corrosion addition t_c for hatch covers **Table 1**

Corrosion addition t_c, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2.0
Top and bottom plating of double skin hatch cover	2.0
Internal structures of double skin hatch cover	1.5

1.5 Allowable stresses

1.5.1

The allowable stresses σ_a, in N/mm^2, are to be obtained from Table 2.

Allowable stresses **Table 2**

Members of	Subjected to	σ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in [4.1.2]	0.80 R_{eH}
Weathertight hatch cover	Other loads, as defined in [4.1.3] to [4.1.6]	0.90 R_{eH} for load combination: S+D 0.72R_{eH} for load combination: S

The allowable buckling utilisation factors are given in Table 3:

Allowable buckling utilisation factors **Table 3**

Structural component	Subject to	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Web of SM	External pressure, as defined in [4.1.2]	0.80 for load combination: S+D
	Other loads, as defined in [4.1.3] to [4.1.6]	0.90 for load combination: S+D 0.72 for load combination: S

2 ARRANGEMENTS

2.1 Hatch covers

2.1.1

The stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.1.2

The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.1.3

The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.1.4

Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.1.5

The width of each bearing surface for hatch covers is to be at least 65 mm.

2.2 Hatch coamings

2.2.1

Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the

clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.2.2
Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.2.3
Longitudinal coamings are to be vertically extended at least to the lower edge of deck beams or hatch side girders below deck are to be fitted in line with longitudinal coamings. Extended coaming plates are to be flanged or fitted with face bars or half-round bars at the level of lower edge of the deck beams. Figure 1 gives an example.

- Where they are not part of continuous deck girders, the lower edge of longitudinal coamings including below deck structure as an extension measure above are to extend for at least two frame spaces beyond the end of the hatch openings.
- Where they are part of continuous deck girders, their scantlings are to be as required in Pt 1, Ch6, Sec 6 and Pt 1, Ch 8, Sec 3.

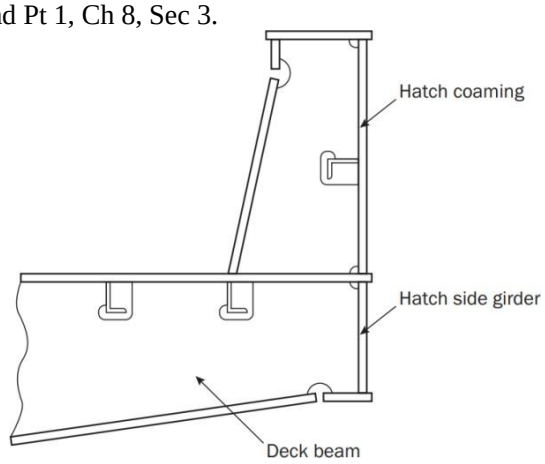


Figure 1 Example of extension to lower edge of deck beams of longitudinal coaming by fitting a hatch side girder

2.2.4
A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

3 WIDTH OF ATTACHED PLATING

3.1 Stiffeners

3.1.1
The width of the attached plating *bp*, in mm, to be considered for the check of stiffeners is to be taken as:

3.1.1 Where the attached plating extends on both sides of the stiffener:

$b_p = s$

3.1.2 Where the attached plating extends on one side of the stiffener:

$b_p = 0.5\ s$

4 LOAD MODEL

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in [4.1.2] to [4.1.6]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the sea pressures defined in [4.1.2] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or

containers, the pressures and forces defined in [4.1.3] to [4.1.6] are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- Still water pressure: $P_S = 0$.
- Wave pressure $P_W = P_{HC}$, as defined in Pt 1, Ch 4, Sec 5, [5.2].

4.1.3 Internal pressures due to ballast water

If applicable, the internal static and dynamic lateral pressures due to ballast water are to be considered and are defined in Pt 1, Ch 4, Sec 6, [1].

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures due to uniform cargoes are to be considered and are defined in Pt 1, Ch 4, Sec 5, [5.3.1].

4.1.5 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case- by-case basis.

ISC 4.1.5a In the case of carriage of special cargoes on the hatch covers which may temporarily retain water during navigation, lateral loads on the hatch covers shall be determined with the method specified in 4.1.4 taking into account the quality of the retained water.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

ISC 4.1.6a In the case of carriage of containers on the hatch covers, the concentrated force P is to be determined by the following formula:

$P=P_S(1+a_Z)$

where:

P_S : *container stack weight, in kN;*

a_Z : *vertical acceleration, in* m/s^2, *see 3.2.4, Section 3, Chapter 4 of PART 9-1.*

4.1.7 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

5 STRENGTH CHECK

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to lateral pressure and/or concentrated loads, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.
It is also applicable for hatch covers fitted with U-type stiffeners as shown in Figure 1. The stresses in all structural members are to be determined by a finite element analysis with the modelling requirements as described in [5.6.1].
It is to be checked that stresses of all structural members comply with the yield strength assessment requirement in [5.6.2], and the buckling strength assessment requirements as described in [5.2.3], [5.3.4], [5.4.6], [5.6.3] and [5.6.4].

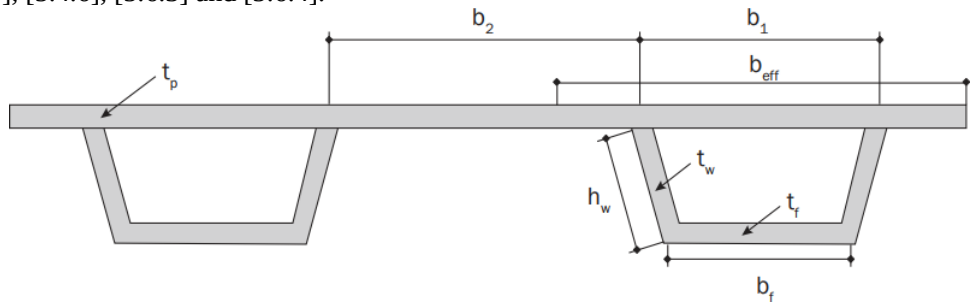


Figure 2 Example of hatch cover fitted with U type stiffener

ISC 5.1.1a When the hatch cover is arranged as a grillage of longitudinal and transverse primary supporting members, it is to be modeled as follows:

(1) The cover geometry is to be idealized as realistically as possible. Element size is to be appropriate to account for effective breadth. In way of force transfer points and cut-outs the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 4.

The element height of webs of primary supporting members is not to exceed one third of the web height. Stiffeners and supporting plates against pressure loads have to be included in the idealization. Buckling stiffeners may be disregarded for the stress calculation.

(2) A right-hand coordinate system is to be used with:
the x-axis measured in the longitudinal direction, positive forward;
the y-axis measured in the transverse direction, positive to port from the centerline;
the z-axis measured in the vertical direction, positive upwards.

(3) Scantlings are to be based on net thicknesses for FE analysis.

(4) The extent of the FE model is to be determined as follows:

① For symmetry of the hatch cover girders, loads and boundary supporting conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check.

② For non-symmetry of hatch cover girders, loads and boundary supporting conditions about any of the axes, the whole hatch cover is to be taken for strength evaluation, see Figure ISC 5.1.1a (1).

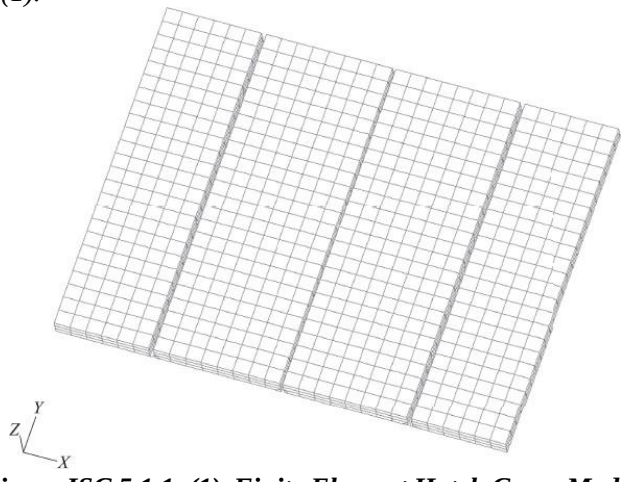


Figure ISC 5.1.1a(1) Finite Element Hatch Cover Model

(5) The model element is to comply with the following requirements:

① *All plating, including girders and stiffeners, is to be represented by the finite element model.*

② *All plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible.*

③ *All stiffeners are to be modeled using beam, rod or plate elements.*

(6) The element mesh size is to be controlled as follows:

① *The mesh size is not to be greater than the spacing of stiffeners.*

② *The girders are to be represented by at least 3 elements in the depth.*

③ *Triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.*

(7) Boundary conditions are to be determined as follows:

① *For symmetry of the hatch cover girders and loads about the x-axis, the longitudinal displacement of nodes in the symmetric plane and the rotations about the y-and z-axes are to be taken as 0, respectively, i.e.* $\delta_x = \theta_y = \theta_z = 0$*, as shown in Figure ISC 5.1.1a(2).*

② *For symmetry of the hatch cover girders and loads about the y-axis, the transverse displacement of nodes in the symmetric plane and rotation about the x-and z-axes are to be taken as 0 respectively i.e.* $\delta_y = \theta_x = \theta_z = 0$*, as shown in Figure ISC 5.1.1a.*

③ *Boundary nodes in way of bearing pads on the hatch coamings are to be fixed against displacement in the z direction in general, i.e.* $\delta_y = 0$.

④ *Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.*

⑤ *Hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the z direction.*

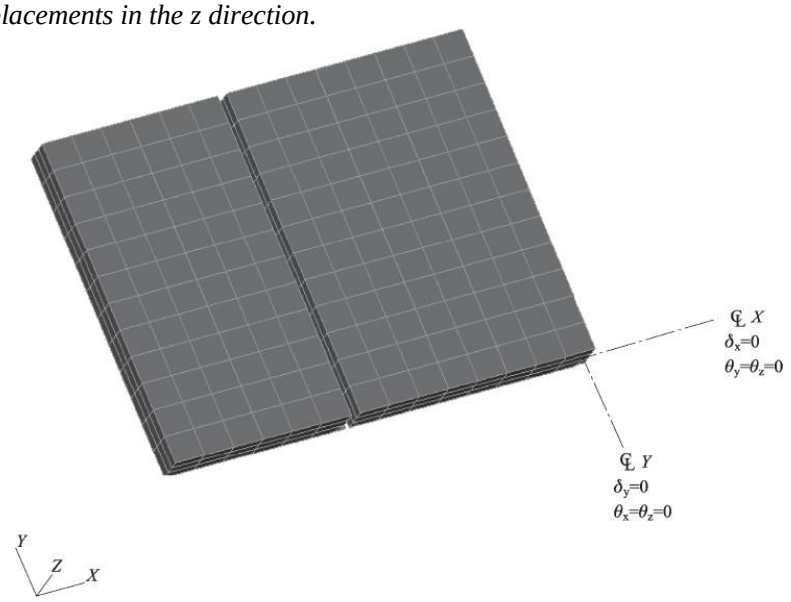


Figure ISC 5.1.1a(2) Boundary Conditions of Hatch Cover Model

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

ISC 5.1.2a The scantlings of hatch covers supporting containers are to comply with the requirements of 5 of this Section, taking into account the container loads in ISC 4.1.6a.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and

their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.4].

5.2 Plating

5.2.1 Net thickness

The net thickness, in mm, of steel hatch cover top plating is not to be taken less than:

$$t = 0.0158 F_p b \sqrt{\frac{F_S P_S + F_W P_W}{0.95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

F_p = 1.5 in general.

$F_p = 1.9\,\sigma/\sigma_a$, for $\sigma \geqslant 0.8\sigma_a$ for the attached plating of primary supporting members.

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$t = b/100$

$t = 6$

5.2.3 Buckling strength

The buckling strength of the hatch cover plating subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

For hatch covers fitted with U type stiffeners, it is to comply with the requirements in [5.6.4].

5.3 Stiffeners

5.3.1

Stiffeners are to comply with the applicable slenderness and proportion requirements given in Pt 1, Ch 8, Sec 2, [3.1.1] and [3.1.2].

5.3.2 Minimum net thickness of web

The net thickness, in mm, of the stiffener web is to be taken not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_S P_S + F_W P_W) s l_s^2}{f_{bc} \sigma_a}$$

$$A_{shr} = \frac{5(F_S P_S + F_W P_W) s l_s}{\tau_a} 10^{-3}$$

where:

l_s : Stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Buckling strength

The buckling strength of the hatch cover stiffeners subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

The buckling strength of the hatch cover fitted with U type stiffeners subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.4].

5.4 Primary supporting members

5.4.1 Application

Primary supporting members are to be checked with the requirements in [5.4.2] to [5.4.5].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than 6 mm.

5.4.3 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self- weight of the structure, is to be such that the deflection does not exceed μl_{max}. where:

μ : Coefficient taken equal to:

μ= 0.0056 for weathertight hatch covers.

l_{max} : Greatest span, in m, of primary supporting members.

5.4.4 Buckling strength of the web panels of the primary supporting members

The web of primary supporting members subject to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

5.4.5 Slenderness criteria

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.5 DELETED

5.5.1

DELETED

Figure 3 DELETED

5.6 Finite element model and buckling assessment

5.6.1 Finite element model

For the strength assessments of hatch covers subjected to loading conditions as defined in [4.1], by means of FE analysis, the hatch cover geometry shall be idealized as realistically as possible. In no case shall the element width be larger than stiffener spacing. In way of force transfer points and cutouts the mesh is to be refined where applicable. The ratio of element length to width shall not exceed 3.

The element size along the height of webs of primary supporting member is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 1 are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

5.6.2 Yield strength assessment

All hatch cover structural members are to comply with the following formula:

$\sigma_{vm} \le \sigma_a$ for shell elements in general.

$\sigma_{axial} \le \sigma_a$ for rod or beam elements in general.

where,

σ_a : Allowable stress as defined in [1.5.1], Table 2.

σ_{vm} :Von Mises stress, in N/mm^2, to be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

σ_x : Normal stress, in N/mm^2, in x-direction.
σ_y : Normal stress, in N/mm^2, in y-direction.
σ_{xy} : Shear stress, in N/mm^2, in the x-y plane.
σ_{axial}:Axial stress in rod or beam element, in N/mm^2.
Indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.
In case of FEM calculations using shell (or plate) elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

5.6.3 Buckling strength assessment

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP). Assessment Method A (-A) and Method B (-B) as defined in Pt 1, Ch 8, Sec 1, [3] are to be used in accordance with Table 4, Figure 3 and Figure 4. For a web panel with opening, the procedure for opening should be used for its buckling assessment.
Wherever necessary, the following corresponding buckling requirements for direct strength anaslysis in Pt 1, Ch 8, Sec 4 can be referred to:

a) Average thickness of plate panel, in Pt 1, Ch 8, Sec 4, [2.1.2].
b) Irregular plate panel, in Pt 1, Ch 8, Sec 4, [2.3].
c) Reference stress, in Pt 1, Ch 8, Sec 4, [2.4].
d) Lateral pressure, in Pt 1, Ch 8, Sec 4, [2.5].
e) Buckling criteria, in Pt 1, Ch 8, Sec 4, [2.6], but using allowable buckling utilisation factors as defined in Pt 2, Ch 1, Sec 5, Table 3.

Structural members and assessment methods Table 4

Structural elements	Assessment method[1,2]	Normal panel definition
Hatch cover top/bottom plating structures, see Figure 3		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover webs of primary supporting members, see Figure 4		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B[3]	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM

(1) SP and UP stand for stiffened and unstiffened panel respectively.
(2) A and B stand for Method A and Method B respectively.
(3) In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.

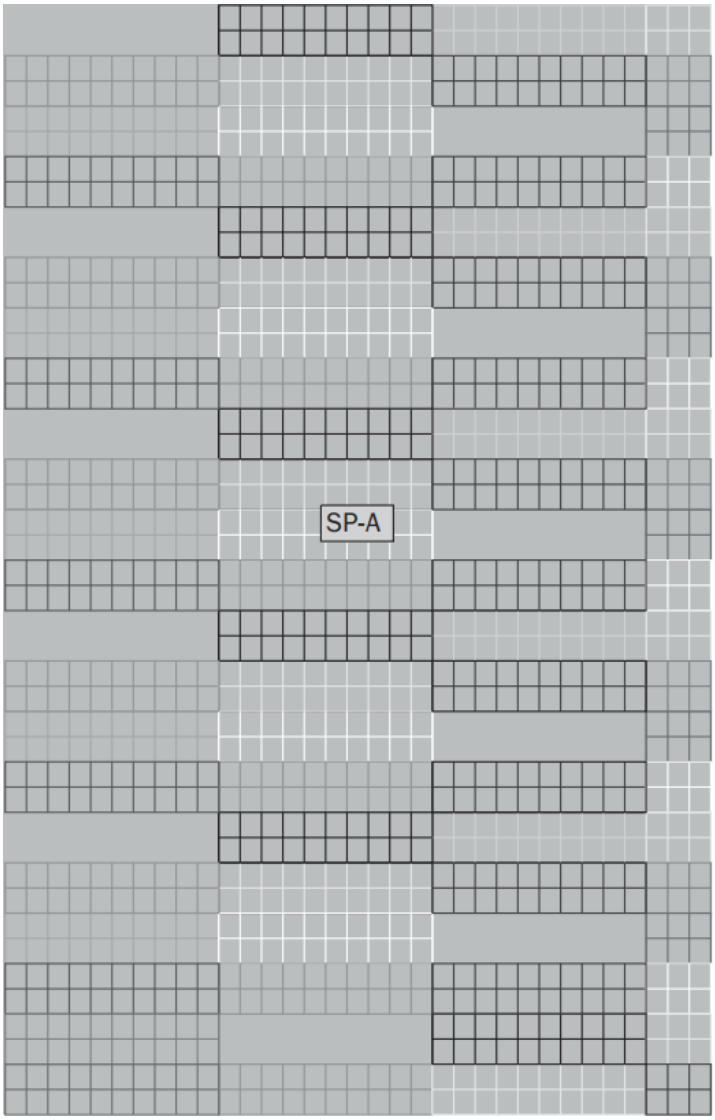


Figure 4 Hatch cover top/bottom plating structures

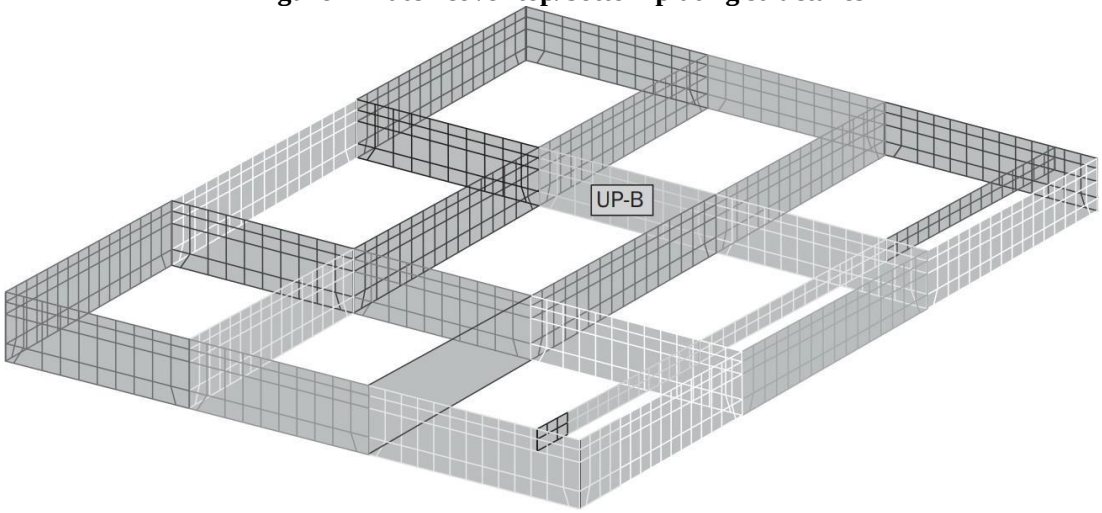


Figure 5 Hatch cover webs of primary supporting members

5.6.4 Buckling assessment of stiffened panels with U-type stiffeners

For hatch covers fitted with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Figure 2) separately as follows:

- The attached plate panels EPP b_1 and b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in Pt 1, Ch 8, Sec 5, Table 3, the correction factor F_{long} for U-type stiffeners as defined in Pt 1, Ch 8, Sec 5, Table 2 is to be used; and in the calculation of K_y as defined in Pt 1, Ch 8, Sec 5, Table 3, the F_{tran} for U-type stiffeners as defined in Pt 1, Ch 8, Sec 5, [2.2.5] is to be used.
- The face plate and web plate panels EPP b_f and h_w are to be assessed using UP-B model with F_{long}=1 and F_{tran}=1.

The overall stiffened panel capacity and ultimate capacity of stiffeners of the hatch cover fitted with U-type stiffeners are to be checked with warping stress σ_w = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

- The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.
- Effective width of the attached plating, b_{eff}, taken as the sum of the b_{eff} calculated for the EPP b_1 and b_2 respectively according to SP-A model.
- Effective width of the attached plating of a stiffener without the shear lag effect, b_{eff1}, taken as the sum of the b_{eff1} calculated for the EPP b_1 and b_2 respectively.

6 HATCH COAMINGS

6.1 Stiffening

6.1.1

The stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

6.1.3

Where the height of the coaming exceeds 900 mm, additional strengthening may be required. However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength.
Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.
In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The wave lateral pressure, P_C in kN/m^2, to be considered as acting on the hatch coamings is defined in [6.2.2] and [6.2.3].

6.2.2

The wave lateral pressure, P_C in kN/m^2, on the No. 1 forward transverse hatch coaming is to be taken equal to:

- P_C = 220, when a forecastle is fitted in accordance with Ch 1, Sec 1, [1].
- P_C = 290, in the other cases.

6.2.3

The wave lateral pressure, P_C in kN/ m^2, on the hatch coamings other than the No. 1 forward transverse hatch coaming is to be taken equal to:
P_C = 220

6.2.4
For cargo holds intended for the carriage of ballast water, the liquid internal pressures applied on hatch coaming is also to be determined according to Pt 1, Ch 4, Sec 6.

6.3 Scantlings

6.3.1 Plating

The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0.016b\sqrt{\frac{p_c}{0.95R_{eH}}}$$

t = 9.5

6.3.2 Stiffeners

The net section modulus, Z, in cm^3, of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1.21\frac{P_c s l^2}{f_{bc} c_p R_{eH}}$$

where:
f_{bc} : Coefficient taken equal to:
f_{bc} = 16 in general.
f_{bc} = 12 for the end span of stiffeners sniped at the coaming corners.
c_p : Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness.
c_p = 1.16 in the absence of more precise evaluation.

6.3.3 Coaming stays

At the connection with deck, the net section modulus Z, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Figure 6 and Figure 7) are to be taken not less than:

$$Z = \frac{s_c P_c H_c^2}{1.9R_{eH}}$$

$$t_w = \frac{s_c P_c H_c}{0.5hR_{eH}}$$

where:
H_C : Stay height, in m.
s_C : Stay spacing, in mm.
h : Stay depth, in mm, at the connection with deck.

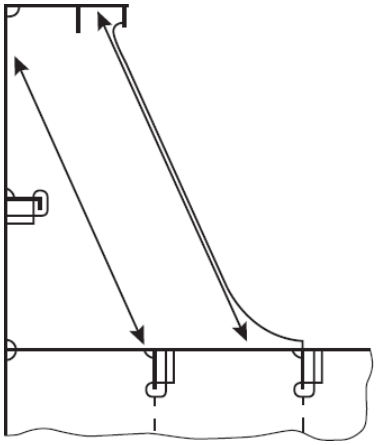


Figure 6 Coaming stay (example 1)

For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

For other designs of coaming stays, such as those shown in Figure 8 and Figure 9, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leqslant 0.95\, R_{eH}$

$\tau \leqslant 0.5\, R_{eH}$

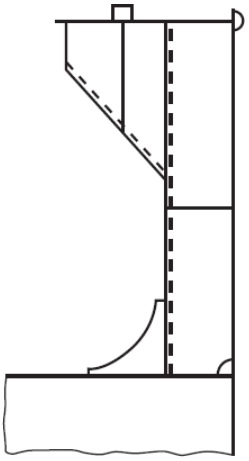


Figure 7 Coaming stay (example 2)

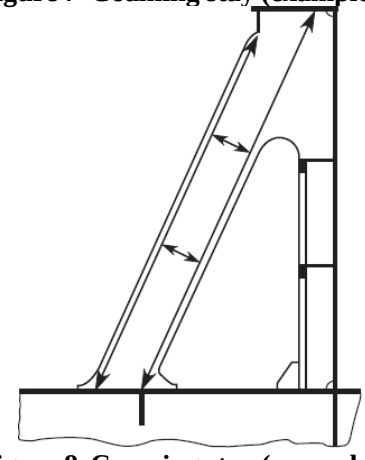


Figure 8 Coaming stay (example 3)

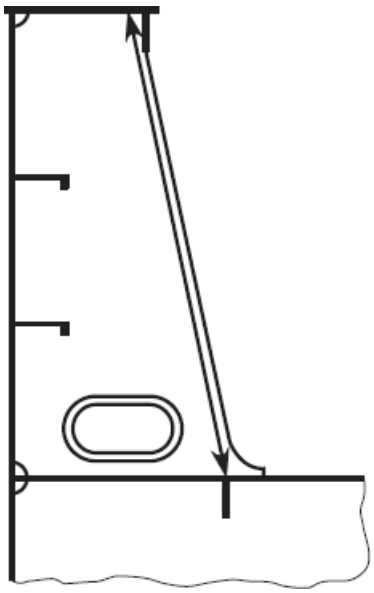


Figure 9 Coaming stay (example 4)

6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress γ, in N/mm^2, induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leqslant 0.95\ R_{eH}$

$\gamma \leqslant 0.5\ R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of the Society.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than 0.62 t_w, where t_w is the gross thickness of the stay web. Toes of stay webs are to be connected to the deck plating with partial penetration double bevel welds extending over a distance not less than 15% of the stay width.

ISC 6.3.4a Unless otherwise stated in this Section, weld connections and materials are to be dimensioned and selected in accordance with the applicable requirements in Table 2.5.2 of Section 3, Chapter 12 and Section 1, Chapter 3 of PART 9-1.

7 WEATHERTIGHTNESS, CLOSING ARRANGEMENT, SECURING DEVICES AND STOPPERS

7.1 Weathertightness

7.1.1

Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure.

7.2.2
The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.
Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3
The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.
If necessary, suitable devices are to be fitted to limit such movements.

7.2.4
The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.
The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.
The gasket is to be effectively secured to the hatch cover.

7.2.5
Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6
Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced along the coamings and between cover elements.
Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to [2.1.2] are to be considered by the Society on a case-by- case basis.

ISC 7.3.1a The closing arrangements, securing devices and stoppers of hatch cover are to comply with the requirements of this Section taking into account the effectiveness of arrangement, spacing, structure, area of securing devices and moment of inertia for edges under situation of special design.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.
Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.
At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.
The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.
Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices
The gross cross area of each securing device is not to be less than the value obtained, in cm^2, from the following formula:

$$A = 1.4 S_S \left(\frac{235}{R_{eH}} \right)^{\alpha}$$

where:
S_S : Spacing, in m, of securing devices.
α : Coefficient taken equal to:
$\alpha = 0.75$ for $R_{eH} > 235$ N/mm^2.
$\alpha = 1.0$ for $R_{eH} \leqslant 235$ N/mm^2.
In the above calculations, R_{eH} may not be taken greater than 0.7 R_m.
Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area *A* is to be increased in direct proportion. The packing line pressure is to be specified.
In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area *A* of the above securing arrangements is to be determined through direct calculations.

ISC 7.3.5a The permissible stress criteria for securing devices of hatch cover is to be:
(1) For securing devices such as rods or bolts, the tensile stress is not to exceed 120/k, N/mm^2.
(2) *For other types of securing devices, the permissible stress is to be as follows:*
normal stress: $\sigma = 120 / k$ N/mm^2
equivalent stress: $\sigma_e = 150 / k$ N/mm^2
shear stress : $\tau = 80 / k$ N/mm^2.

7.3.6 Inertia of edges elements
The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.
The moment of inertia of edge elements is not to be less than the value obtained, in cm4, from the following formula:

$$I = 6 p_L S_S^4$$

where:
P_L: Packing line pressure, in N/mm, to be taken not less than 5.
S_S: Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts
Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m2 in area.

7.3.8 Stoppers
Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.
With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal

forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Ch 1, Sec 1, [1].

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 R_{eH}.

7.4 Cleats

7.4.1

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.4.2

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8 DRAINAGE

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship’s structure, drainage from the space between the steel contact and the gasket is also to be provided.

Section 6 ADDITIONAL CLASS NOTATION GRAB

SYMBOLS

M_{GR} *:* Mass of unladen grab, in t.

1 GENERAL

1.1 Application

1.1.1

The additional class notation GRAB [X] is assigned, in accordance with Pt 1, Ch 1, Sec 1, [3.2.2], to ships with holds designed for loading/unloading by grabs having a maximum mass of unladen grab, in tons up to [X] tons, in compliance with the requirements of this section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

2 SCANTLINGS

2.1 Plating

2.1.1 General

The net thickness of plating of inner bottom and vertical sloped cargo hold; excluding bilge wells, is to be taken as the greater of the following values:

- t, as obtained according to requirements in Pt 1, Ch 6 and Pt 1, Ch 7.
- t_{GR}, as defined in [2.1.2] and [2.1.3].

2.1.2 Inner bottom plating

The net thickness t_{GR}, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.62\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

2.1.3 Vertical and sloped cargo hold boundaries

The net thickness t_{GR}, in mm, as defined in this sub-section apply to the following structural elements.

- Hopper tank sloped plating.
- Transverse lower stool plating.
- Transverse plane bulkhead plating.
- Face plates of transverse corrugated bulkheads without lower stool.
- Inner hull

Up to a height of 3.0 m above, the lowest point of the inner bottom is to be obtained from the following formula:

$$t_{GR} = 0.55\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

Chapter 2 OIL TANKERS

SECTION 1 GENERAL ARRANGEMENT DESIGN

1 GENERAL

1.1 General

1.1.1

This section covers the general structural arrangement requirements for oil tankers, which are based on national and international regulations.

2 SEPARATION OF CARGO TANKS

2.1 General

2.1.1

The designer's attention is to be drawn on the arrangement of the cargo pump room, cargo tanks, slop tanks and cofferdams, main cargo control stations, control stations, accommodation and service spaces as well as on the need to separate the cargo tanks from the machinery space.

3 DOUBLE HULL ARRANGEMENT

3.1 General

3.1.1

All oil tankers are to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with Pt 1, Ch 2, Sec 3. The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2

Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

4 ACCESS ARRANGEMENTS

4.1 Special requirements for oil tankers

4.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door.

Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

4.1.2

Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society and the following additional requirements:

a) The watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

b) A notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

ISC 4.1.2a The strength of watertight doors is to be equivalent to that of the surrounding structure and to comply with the recognized standard.

4.1.3
Special consideration is to be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant national regulations concerning load line and oil outflow aspects of such arrangements.

SECTION 2 STRUCTURAL DESIGN PRINCIPLES

1 CORROSION PROTECTION

1.1 General

1.1.1 Cathodic protection systems in cargo tanks

Cathodic protection systems, if fitted in cargo tanks, are to comply with [1.2].

1.1.2 Paint containing aluminium

Paint containing aluminium, when used in cargo tanks, is to comply with [1.3].

1.2 Internal cathodic protection systems

1.2.1

When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60°C, a plan of the fitting arrangement is to be submitted for approval. The arrangements are to be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

1.2.2

Permanent magnesium or magnesium alloy anodes in tanks are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks.

Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion.

Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60°C and in adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275 J is developed in the event of their loosening and becoming detached.

1.2.3

Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

1.2.4

Tanks, in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

1.3 Paint containing aluminium

1.3.1

The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate

1.3.2

Aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

SECTION 3 HULL LOCAL SCANTLING

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

S : Primary supporting member spacing as defined in Pt 1, Ch 3, Sec 7, [1.2.2], in m.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

$C_{s\text{-}pr}$: Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s\text{-}pr}$ = 0.70 for AC-S.

$C_{s\text{-}pr}$ = 0.85 for AC-SD.

s_{cg} : Half pitch length of corrugation, in mm. See Figure 4.

l_{cg} : Length of corrugation, in m, which is defined as the distance between the lower stool and the upper stool. Where no lower or upper stool is fitted, l_{cg} is to be measured to lower or upper end as shown in Figure 4.

1 PRIMARY SUPPORTING MEMBERS IN CARGO HOLD REGION

1.1 General

1.1.1

The following requirements relate to the determination of scantlings of the primary supporting members within 0.4 L amidships and those outside 0.4 L amidships provided that the geometry and fixation of primary supporting member is similar with those amidships.

1.1.2

The section modulus and shear area criteria for primary supporting members contained in this sub-section apply to structural configurations shown in Pt 1, Ch 1, Sec 1, Figure 3 and are applicable to the following structural elements:

a) Floors and girders within the double bottom,
b) Deck transverses,
c) Side transverses within double side structure,
d) Vertical web frames on longitudinal bulkheads with or without cross ties,
e) Horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports,
f) Cross ties in wing cargo and centre cargo tanks.

1.1.3

Floors, horizontal stringers, side transverses and vertical webs adjacent to transverse bulkheads which get additional supports by horizontal stringers or buttresses are excluded from the application of this section.

1.1.4

Webs of the primary supporting members are to be stiffened in accordance with Pt 1, Ch 8, Sec 2, [4].

1.1.5

Webs of the primary supporting members are to have a depth of not less than given by the requirements of [1.5.1], [1.7.1] and [1.8.1], as applicable.

1.1.6

In any case, primary supporting members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots if slots are not closed.

1.1.7

Where it is impracticable to fit a primary supporting member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required member. The required equivalent moment of

inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus.
The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.
All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth.

1.2 Design load sets

1.2.1

The design load sets for the evaluation of primary supporting members are given in Table 1.

Design load sets for primary supporting members **Table 1**

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
Double bottom floors and girders (3)	SEA-1	P_{ex}	$0.9T_{sc}$ (2)	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{sc}	S	
	OT-4	$P_{in} - P_{ex}$	$0.6T_{sc}$	S+D	Net pressure difference between cargo pressure and sea pressure
	OT-5	$P_{in} - P_{ex}$	(4)	S	
Side transverses (3)	SEA-1	P_{ex}	$0.9T_{sc}$	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{sc}	S	
	OT-1	P_{in}	T_{sc}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Deck transverses	SEA-1	P_{ex}	T_{sc}	S+D	Green sea pressure only or other loads on deck
	OT-1	P_{in}	T_{sc}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6\ T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Vertical web frames on longitudinal bulkheads	OT-1	P_{in}	T_{sc}	S+D	Pressure from one side only. Full cargo tank with adjacent cargo tank empty
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Horizontal stringers on transverse bulkhead	OT-1	P_{in}	T_{sc}	S+D	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty.
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in centre tanks	OT-1	$\frac{P_{in-pt}+P_{in-stb}}{2}$	T_{SC}	S+D	Full wing cargo tanks, centre tank empty.
	OT-2	$\frac{P_{in-pt}+P_{in-stb}}{2}$	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in wing tanks	OT-6	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}	S+D	Full centre tank, wing cargo tanks

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
	OT-7	$\frac{P_{in}+P_{ex}}{2}$	$0.6T_{sc}$	S+D	empty.
	OT-8	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}	S	

where:

$P_{in\text{-}pt}$: Design pressure from port side wing cargo tank, in kN/m^2.

$P_{in\text{-}stb}$: Design pressure from starboard side wing cargo tank, in kN/m^2.

(1) The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1.

(2) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than 0.9 T_{sc} is included in ship's loading manual, the maximum corresponding draught is to be considered.

(3) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in Pt 1, Ch 4, Sec 8, [2] and Pt 1, Ch 4, Sec 8, [3]. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.

ISC (3) Where the optional loading conditions exceed the minimum Rule required loading conditions, the most unfavorable draught between the actual draught and the Rule required draught is to be taken if the minimum Rule required draught is exceeded.

(4) For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as 0.25 T_{sc}. For tankers with a centreline bulkhead, the draught is to be taken as 0.33 T_{sc}.

(5) When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to specify all applicable cases from the following:

- A full tank on one side of the member with the tank or space on the other side empty.
- A full tank on one side of the member with the external pressure minimised.
- External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected.

(6) For a void or dry space, the pressure component from the void side is to be ignored.

1.3 Floors in double bottom

1.3.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

1.3.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the floors at any position in the floor is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN.

$Q = f_{shr}\, PSl_{shr}$

f_{shr} :Shear force distribution factor:

$$f_{shr} = f_{shr-i}\left(1-\frac{2y_i}{l_{shr}}\right) \text{ but not to be taken as less than } 0.2$$

$f_{shr\text{-}i}$: Shear force distribution factor at the end of the span, l_{shr}, as given in Table 2.

l_{shr} : Effective shear span, of the double bottom floor, in m, as shown in Figure 2. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Pt 1, Ch3, Sec 7, [1.1.7]. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Figure 2.

y_i : Distance from the considered cross section of the floor to the nearest end of the effective shear span, l_{shr} in m.

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid point of effective shear span, l_{shr} of a floor located midway between transverse bulkheads or

transverse bulkhead and wash bulkhead, where fitted, in kN/m^2.

Shear force distribution factors of floors **Table 2**

Structural configuration	Centre tank (f_{shr3} in Figure 1)	Wing tank	
		At inboard end (f_{shr2} in Figure 1)	At hopper knuckle end (f_{shr1} in Figure 1)
Ships with centreline longitudinal bulkhead	-	0.40	0.60
Ships with two longitudinal bulkheads	0.5	0.50	0.65

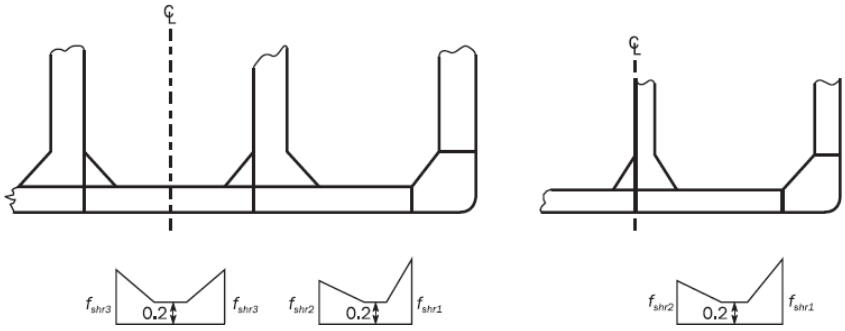
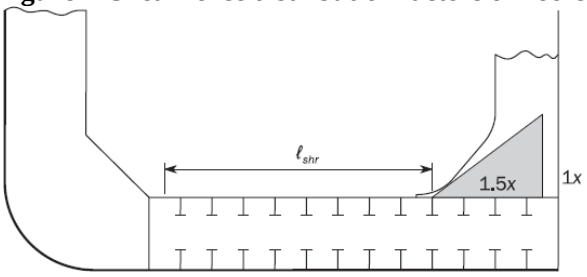
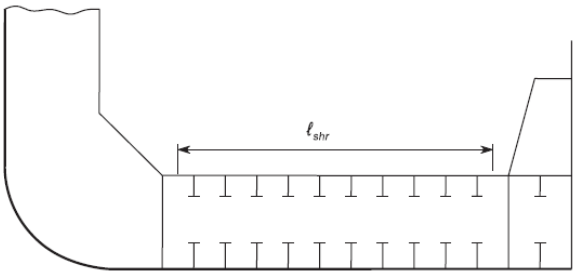


Figure 1 Shear force distribution factors of floors



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

Figure 2 Effective shear span of floors

1.4 Girders in double bottom

1.4.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools.

1.4.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN, taken as:

$$Q = 0.21 n_1 n_2 P l^2_{shr}$$

l_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

n_1 : Coefficient taken as:

$$n_1 = 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$$

n_2 : Coefficient taken as:

$$n_2 = 1.3 - \left(\frac{S}{12}\right)$$

S : Double bottom floor spacing, in m, as defined in Pt 1 Ch 3 Sec 7 [1.2.2].

1.4.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in cm^2, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0.14 n_3 n_4 P l^2_{shr}$$

n_3 : Coefficient taken as:

$$n_3 = 1.072 - 0.0357\left(\frac{l_{shr}}{S}\right)$$

n_4 : Coefficient taken as:

$$n_4 = 1.2 - \left(\frac{S}{18}\right)$$

S : Double bottom floor spacing, in m, as defined in Pt 1 Ch 3 Sec 7 [1.2.2].

l_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

1.5 Deck transverses

1.5.1 Web depth

The web depth of under deck transverses is not to be less than:

- 0.20 l_{bdg-dt} for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads.
- 0.13 l_{bdg-dt} for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank.
- 0.10 l_{bdg-dt} for the deck transverses of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

The web depth of above deck transverses is not to be less than:

- 0.10 l_{bdg-dt}
- The web height required in[1.1.6].

where:

l_{bdg-dt}: Effective bending span, in m, as defined in [1.5.2].

1.5.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in cm^3, is not to be less than Z_{in-n50} and Z_{ex-n50} as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850 M_{in}}{C_{s-pr} R_{eH}}$$

$$Z_{ex-n50} = \frac{850 M_{ex}}{C_{s-pr} R_{eH}}$$

where:

M_{in} : Design bending moment due to cargo pressure, in kNm, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead: $M_{in} = 0.042 \varphi_t P_{in\text{-}dt} Sl^2_{\ bdg\text{-}dt} + M_{st}$ but is not to be taken as less than M_0.
- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads: $M_{in} = 0.042 \varphi_t P_{in\text{-}dt} Sl^2_{\ bdg\text{-}dt} + M_{vw}$ but is not to be taken as less than M_0

M_{st} : Bending moment transferred from the side transverse, in kNm:

$M_{st} = c_{st} \beta_{st} P_{in\text{-}st} Sl^2_{\ bdg\text{-}dt}$

where a cross tie is fitted in a wing cargo tank and $l_{bdg\text{-}st\text{-}ct}$ is greater than 0.7 $l_{bdg\text{-}st}$, then $l_{bdg\text{-}st}$ in the above formula may be taken as $l_{bdg\text{-}st\text{-}ct}$.

M_{vw}: Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in kNm:

$M_{st} = c_{vw} \beta_{vw} P_{in\text{-}vw} Sl^2_{\ bdg\text{-}vw}$

where $l_{bdg\text{-}vw\text{-}ct}$ is greater than 0.7 $l_{bdg\text{-}vw}$, then $l_{bdg\text{-}vw}$ in the above formula may be taken as $l_{bdg\text{-}vw\text{-}ct}$. For vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses.

M_0 : Minimum bending moment, in kNm.

$M_0 = 0.083 P_{in\text{-}dt} Sl^2_{\ bdg\text{-}dt}$

M_{ex} : Design bending moment due to green sea pressure, in kNm.

$M_{ex} = 0.067 P_{ex\text{-}dt} Sl^2_{\ bdg\text{-}dt}$

$P_{in\text{-}dt}$: Design cargo pressure given in Table 1 for the design load set being considered, calculated at mid- point of effective bending span, $l_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2.

$P_{in\text{-}st}$: Corresponding design cargo pressure in wing cargo tank given in Table 1 for the design load set being considered, calculated at the mid-point of effective bending span, $l_{bdg\text{-}st}$ of the side transverse located at mid-tank, in kN/m^2.

$P_{in\text{-}vw}$: Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}vw}$ of the vertical web frame on the longitudinal bulkhead located at mid- tank, in kN/m^2.

$P_{ex\text{-}dt}$: Design green sea pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2.

φ_t : Coefficient taken as:

$$\varphi_t = 1 - 5\left(\frac{y_{toe}}{l_{bdg-dt}}\right) \text{ but not taken less than } 0.6.$$

y_{toe} : Distance from the end of effective bending span, $l_{bdg\text{-}dt}$ to the toe of the end bracket of the deck transverse, in m.

β_{st} : Coefficient taken as:

$$\beta_{st} = 0.9\left(\frac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{st-n50}}\right) \text{ but not taken less than } 0.10 \text{ or greater than } 0.65.$$

β_{vw} : Coefficient taken as:

$$\beta_{vw} = 0.9\left(\frac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{vw-n50}}\right) \text{ but not taken less than } 0.10 \text{ or greater than } 0.50$$

$l_{bdg\text{-}dt}$: Effective bending span of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3, but is not to be taken as less than 60% of the breadth of the tank at the location being considered.

$l_{bdg\text{-}st}$: Effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$l_{bdg\text{-}st\text{-}ct}$: Effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see Pt 1, Ch 3, Sec 7, [1.1.6].

$l_{bdg\text{-}vw}$: Effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$l_{bdg\text{-}vw\text{-}ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see Pt 1, Ch 3, Sec 7, [1.1.6].

$I_{dt\text{-}n50}$: Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

$I_{st\text{-}n50}$: Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

$I_{vw\text{-}n50}$: Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

c_{st} : Coefficient given in Table 3.

c_{vw} : Coefficient given in Table 3.

Values of c_{st} and c_{vw} for deck transverses **Table 3**

Structural configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	-	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $l_{bdg\text{-}st\text{-}ct}$ or M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	0.044	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.041	0.015

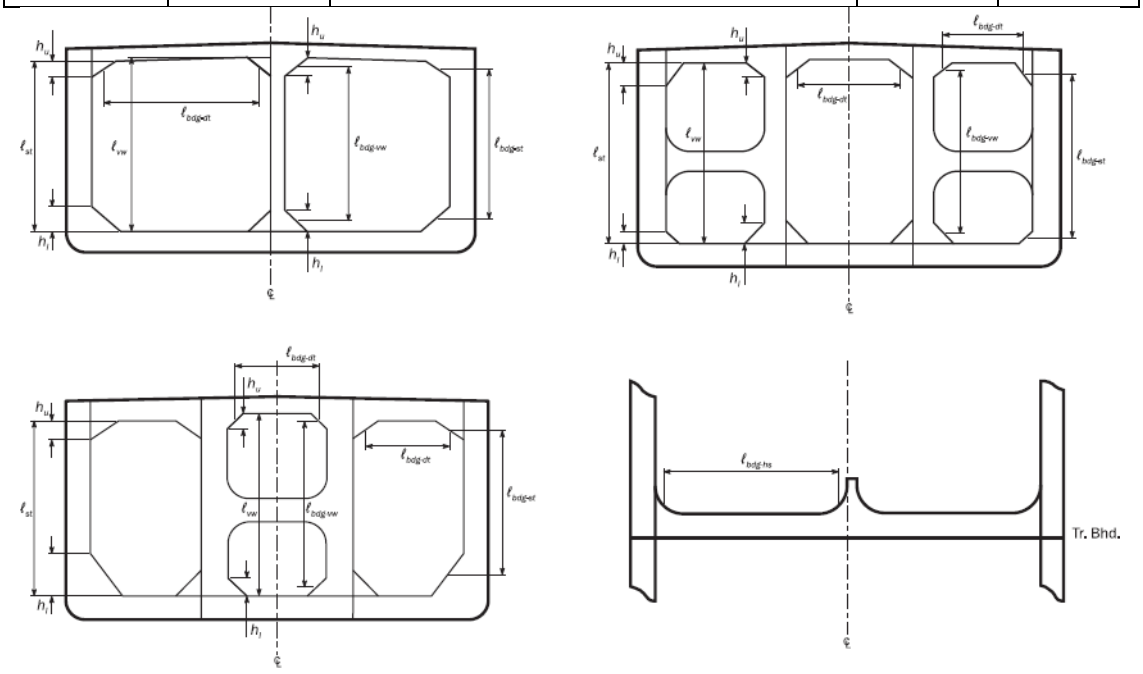


Figure 3 Definition of spans of deck, side transverses, vertical web frames on longitudinal bulkheads and horizontal stringers on transverse bulkheads

1.5.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in cm^2, is not to be less than $A_{shr\text{-}in\text{-}n50}$ and $A_{shr\text{-}ex\text{-}n50}$ as given by:

$$A_{shr-in-n50} = \frac{8.5Q_{in}}{C_{t-pr}\tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8.5Q_{ex}}{C_{t-pr}\tau_{eH}}$$

where:

Q_{in} : Design shear force due to cargo pressure, in kN.

$Q_{in} = 0.65P_{in\text{-}dt}Sl_{shr} + c_1Db_{ctr}S\rho_L g$

Q_{ex} : Design shear force due to green sea pressure, in kN.

$Q_{ex}=0.65P_{ex\text{-}dt}Sl_{shr}$

$P_{in\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$P_{ex\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$l_{bdg\text{-}dt}$: Effective span, in m, defined in [1.5.2].

l_{shr} : Effective shear span, of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.7].

c_1 : Coefficient taken as:

- c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads.
- c_1 = 0.00 in way of centre tank of ships with two longitudinal bulkheads.
- c_1 = 0.00 for ships with a centreline longitudinal bulkhead.

b_{ctr} : Breadth of the centre tank, in m.

1.5.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than Z_{n50} and $A_{shr\text{-}n50}$, in cm^3 and cm^2 respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$Z_{n50} = \frac{850|P|Sl_{bdg}{}^2}{f_{bdg}C_{s-pr}R_{eH}}$$

$$A_{shr-n50} = \frac{8.5f_{shr}|P|Sl_{shr}}{C_{t-pr}\tau_{eH}}$$

where:

P : Design pressure given in Table 1 for the design load set being considered, calculated at midpoint of effective bending span, l_{bdg} of the deck transverse located at mid tank, in kN/m2.

f_{bdg} : Coefficient taken as:

f_{bdg} = 12 for design load set OT-1, OT-2 and OT-3 as defined in Table 1.

f_{bdg} = 15 for design load set SEA-1 as defined in Table 1.

f_{shr} : Coefficient taken as:

f_{shr} = 0.5

l_{bdg} : Effective bending span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

l_{shr} : Effective shear span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with Pt 1, Ch 7 and with in consideration of loading patterns A1, A2 or B1, B2 as defined in Pt 1, Ch 4, Sec 8, [3.2.9] with draught equal to T_{sc} and cargo density of 1.025 t/m^3.

1.5.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of [1.5.2] to [1.5.4] for design green sea pressure only.

1.6 Side transverses

1.6.1 Net shear area

The net shear area, $A_{shr\text{-}n50}$, in cm^2, of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{s-pr}\tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the side transverse.

$Q = Q_l$ for lower part of the side transverse.

Q_u : Shear force, in kN, taken as:

$Q_u = S[\, c_u\, l_{st}\, (P_u + P_l)\, - h_u P_u]$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7 l_{st}$, then l_{st} in the above formula is taken as $l_{st\text{-}ct}$.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S[c_l l_{st}(P_u + P_l) - h_l P_l]$
- $0.35 c_l S l_{st}(P_u + P_l)$
- $1.2 Q_u$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7 l_{st}$, then l_{st} in the above formula is taken as $l_{st\text{-}ct}$.

P_u : Design pressure given in Table 1 for the design load set being considered, in kN/m^2, calculated at mid length of tank and at mid height of h_u.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid height h_l located at mid length of tank, in kN/m^2.

l_{st} : Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see Figure 3.
- Where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom.

$l_{st\text{-}ct}$: Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, $l_{st\text{-}ct}$ is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank.
- Where deck transverses are fitted above deck, $l_{st\text{-}ct}$ is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank.

h_u : Effective length of upper bracket of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, *hu* is as shown in Figure 3.
- Where deck transverses are fitted above deck:
  - When an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, h_u is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:
    - The breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and.
    - The angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 deg or more to vertical.
  - In the other cases: *hu* is taken as 0.

h_l : Height of bilge hopper, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 4.

c_l : Coefficient defined in Table 4.

Values of c_u and c_l for side transverses **Table 4**

Structural configuration			c_u		c_l	
Number of side stringers			Less than three	Equal to or greater than three	Less than three	Equal to or greater than three
Ships with a centreline longitudinal bulkhead			0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank					
	Cross ties in wing cargo tanks	Q_u or Q_l based on l_{st-ct}				
		Q_u or Q_l based on l_{st}	0.08		0.20	

1.6.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}.
b) The required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}.
c) Where Q_u and Q_l are determined based on l_{st-ct}, the required shear area for the lower part is also to be maintained below the cross tie.
d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid- span.
e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

l_{shr} : Effective shear span of the side transverse, in m.

$l_{shr} = l_{st} - h_u - h_l$ where Q_u and Q_l are determined based on l_{st}.

$l_{shr} = l_{st-ct} - h_u$ where Q_u and Q_l are determined based on l_{st-ct}.

l_{st}, l_{st-ct}, h_u, h_l, Q_u, Q_l : Parameters defined in [1.6.1].

1.7 Vertical web frames on longitudinal bulkhead

1.7.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- 0.14 l_{bdg-vw} for ships with a centreline longitudinal bulkhead.
- 0.09 l_{bdg-vw} for ships with two longitudinal bulkheads.
- The web height required in [1.1.6].

where:

l_{bdg-vw} : Effective bending span, in m, defined in [1.7.2].

1.7.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the vertical web frame is not to be less than:

$$Z_{net\,50} = \frac{850M}{C_{s-pr}\sigma_{yd}}$$

where:

M : Design bending moment, in kNm, as follows:

$M = c_u P S l^2_{bdg-vw}$ for upper part of the web frame.

$M = c_l P S l^2_{bdg-vw}$ for lower part of the web frame.

where a cross tie is fitted and $l_{bdg-vw-ct}$ is greater than $0.7 l_{bdg-vw}$, then l_{bdg-vw} in the above formula is to be taken as $l_{bdg-vw-ct}$.

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of the effective bending span, l_{bdg-vw} of the vertical web frame located at mid tank, in kN/m^2.

l_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see Figure 3.

$l_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the

deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in m.

c_u : Coefficient defined in Table 5.

c_l : Coefficient defined in Table 5.

Values of c_u and c_l for vertical web frame on longitudinal bulkheads Table 5

Structural configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.012	0.028
	Cross ties in wing cargo tanks	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.016	0.032

1.7.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required section modulus for the upper part is to be maintained over the upper 0.2 $l_{bdg\text{-}vw}$ or 0.2 $l_{bdg\text{-}vw\text{-}ct}$ as applicable.

b) The required section modulus for the lower part is to be maintained over the lower 0.2 $l_{bdg\text{-}vw}$ or 0.2$l_{bdg\text{-}vw\text{-}ct}$ as applicable.

c) Where the required section modulus is determined based on $l_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.

d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

$l_{bdg\text{-}vw}$, $l_{bdg\text{-}vw\text{-}ct}$: Effective bending span, in m, defined in [1.7.2].

1.7.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the web frame.

$Q = Q_l$ for lower part of the web frame.

Q_u : Shear force, in kN, taken as:

$Q_u = S[c_u l_{vw}(P_u + P_l) - h_u P_u]$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S[c_l l_{vw}(P_u + P_l) - h_l P_l]$
- $c_w S c_l l_{st} (P_u + P_l)$
- $1.2\ Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7\ l_{vw}$, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

P_u : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of upper bracket of the vertical web frame, *hu* located at mid tank, in kN/m^2.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of lower bracket of the vertical web frame, *hl* located at mid tank, in kN/m^2.

l_{vw}: Length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see Figure 3.

$l_{vw\text{-}ct}$: Length of the vertical web frame, in m, between the flange of the deck transverse and mid-depth of the cross tie, where fitted.

h_u : Effective length of upper bracket of the vertical web frame, in m, as shown in Figure 3.

h_l : Effective length of lower bracket of the vertical web frame, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 6.
c_l : Coefficient defined in Table 6.
c_w: Coefficient taken as:

- c_w = 0.57 for ships with a centreline longitudinal bulkhead,
- c_w = 0.50 for ships with two longitudinal bulkheads.

Values of c_u and c_l for vertical web frame on longitudinal bulkhead Table 6

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Qu or Q_l based on l_{vw-ct}		
	Q_u or Q_l based on l_{vw}	0.075	0.18

1.7.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}.
b) The required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}.
c) Where Q_u and Q_l are determined based on l_{vw-ct}, the required shear area for the lower part is also to be maintained below the cross tie.
d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.
e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:
l_{shr} : Effective shear span of the vertical web frame, in m.
$l_{shr} = l_{vw} – h_u – h_l$ where Q_u and Q_l are determined based on l_{vw}.
$l_{shr} = l_{vw} – c_t – h_u$ where Q_u and Q_l are determined based on l_{vw-ct}.
l_{vw}, l_{vw-ct}, h_u, h_l, Q_u, Q_l: Parameters defined in [1.7.4].

1.8 Horizontal stringers on transverse bulkheads

1.8.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- 0.28l_{bdg-hs} for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- 0.20 l_{bdg-hs} for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks.
- 0.20 l_{bdg-hs} for horizontal stringers of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

where:
l_{bdg-hs} : Effective bending span, in m, defined in [1.8.2].

1.8.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the horizontal stringer over the end 0.2 l_{bdg-hs} is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}R_{eH}}$$

where:
M : Design bending moment, in kNm.
P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, l_{bdg-hs} and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2.
l_{bdg-hs} : Effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see Figure 3.

c : Coefficient taken as:

- c = 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead.
- c = 0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- c = 0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

1.8.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends , intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.8.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the horizontal stringer over the end 0.2 l_{shr} is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN.

$Q = 0.5PS_{hs}\, l_{shr}$

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2.

S_{hs} : Spacing, in m, defined in [1.8.2].

l_{shr} : Effective shear span of the horizontal stringer, in m.

1.8.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.9 Cross ties

1.9.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, W_{ct} is to be less than or equal to the permissible load,

$W_{ct\text{-}perm}$ as given by:

$W_{ct} \leqslant W_{ct-perm}$

where:

W_{ct} : Applied axial load, in kN.

$W_{ct} = Pb_{ct}S$

$W_{ct\text{-}perm}$: Permissible load, in kN.

$W_{ct\text{-}perm}=0.12A_{ct\text{-}n50}\eta_{all}\sigma_{cr}$

P : Maximum design pressure for all the applicable design load sets being considered given in Table 1, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2.

b_{ct} : Span, in m, taken as:

- Cross tie fitted in centre cargo tank: $b_{ct} = 0.5l_{bdg\text{-}vw}$
- Cross ties fitted in wing cargo tanks:
  - $b_{ct} = 0.5l_{bdg\text{-}vw}$ for design cargo pressure from the centre cargo tank.
  - $b_{ct} = 0.5\, l_{bdg\text{-}st}$ for design sea pressure.

$l_{bdg\text{-}vw}$: Effective bending span, in m, defined in [1.5.2].

$l_{bdg\text{-}st}$: Effective bending span, in m, defined in [1.5.2].

η_{all} : Allowable buckling utilisation factor as defined in Pt 1, Ch 8, Sec 1, [3.3].

σ_{cr} : Critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the

net sectional properties in accordance with Pt 1, Ch 8, Sec 5, [3.1.1].

$A_{ct\text{-}n50}$: Net cross sectional area of the cross tie, in cm^2.

1.9.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

1.9.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2 VERTICALLY CORRUGATED BULKHEADS

2.1 Application

2.1.1

In addition to the requirements of Pt 1, Ch 6, Sec 4, [1], vertically corrugated bulkheads of oil tankers are also to comply with the requirements of [2.2].

2.2 Scantling requirements

2.2.1 Net plate thickness over the height

The net plate thicknesses as required by [2.2.3] and [2.2.4] are to be maintained for two thirds of the corrugation length, l_{cg} from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in [2.2.3] for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with [2.2.4].

2.2.2 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, *tw* in mm, is to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000\left|Q_{cg}\right|}{d_{cg} C_{t-cg} \tau_{eH}}$$

where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation, in kN.

$$Q_{cg} = \frac{s_{cg} l_{cg} \left|3P_l + P_u\right|}{8000}$$

P_l : Design pressure given in Pt 1, Ch 6, Sec 2, Table 1 for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2.

P_u : Design pressures given in Pt 1, Ch 6, Sec 2,Table 1 for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2.

d_{cg} : Depth of corrugation, in mm, see Figure 4.

$C_{t\text{-}cg}$: Permissible shear stress coefficient:

$C_{t\text{-}cg}$ = 0.75 for acceptance criteria set AC-S.

$C_{t\text{-}cg}$ = 0.90 for acceptance criteria set AC-SD.

2.2.3 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, *tf* in mm, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6.57\, b_{f-cg} \sqrt{\sigma_{bdg-max}}}{C_f} 10^{-3}$$

where:

$\sigma_{bdg\text{-}max}$: Maximum value of the vertical bending stresses in N/mm^2 in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length.

$$\sigma_{bdg-\max} = \frac{M_{cg}}{Z_{cg-act}} 10^3$$

M_{cg} : Vertical bending moment, in kNm, as defined in [2.2.4].

$Z_{cg\text{-}act}$: Actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3.

$b_{f\text{-}cg}$: Breadth of flange plating, in mm. See Figure 4.

$b_{w\text{-}cg}$: Breadth of web plating, in mm. See Figure 4.

C_f : Coefficient taken as:

$$C_f = 7.65 - 0.26(\frac{b_w}{b_f})^2$$

2.2.4 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation (l_{cg} / 2) of a unit corrugation, Z_{cg} are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2] and given by the following.

$$Z_{cg} = \frac{1000 M_{cg}}{C_{s-cg} R_{eH}}$$

where:

M_{cg} : Vertical bending moment in kNm.

$$M_{cg} = \frac{C_i |P| s_{cg} l_0^2}{12000}$$

P : Averaged pressure in kN/m^2.

$$P = \frac{P_u + P_l}{2}$$

P_l, P_u : Design pressure given in Pt 1, Ch 6, Sec 2, Table 1 for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:

- For transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk} / 2 from the longitudinal bulkheads of each tank.
- For longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead, in m.

l_o : Effective bending span of the corrugation, in m, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, l_o is to be measured to lower or upper end. See Figure 4.

C_i : Bending moment coefficient given in Table 7.

$C_{s\text{-}cg}$: Permissible bending stress coefficient at the mid-length of the corrugation length, l_{cg}:

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.75 for acceptance criteria set AC-S.

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.90 for acceptance criteria set AC-SD.

At the lower and upper ends of the corrugation length, l_{cg}:

$C_{s\text{-}cg} = 0.75$ for acceptance criteria set AC-S.

$C_{s\text{-}cg} = 0.90$ for acceptance criteria set AC-SD.

c_e : Coefficient taken as:

$$c_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for} \quad \geqslant 1.25$$

$$c_e = 1.0 \quad \text{for} \quad < 1.25$$

β : Coefficient taken as:

$$\beta = \frac{b_{f-cg}}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Breadth of flange plating, in mm, see Figure 4.
t_f : Net thickness of the corrugation flange, in mm.

Values of C_i **Table 7**

Bulkhead	At lower end of l_{cg}	At mid-length of l_{cg}	At upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	0.65 C_{m1}
Longitudinal bulkhead	C_3	C_{m3}	0.65 C_{m3}

where:
C_1 : Coefficient taken as:

$$C_1 = a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$$ but taken not less than 0.60.

$$C_1 = a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$$ for transverse bulkhead with no lower stool, but taken not less than 0.55.

a_1 : Coefficient taken as:

$$a_1 = 0.95 - \frac{0.41}{R_{bt}}$$

a_1 =1.0 for transverse bulkhead with no lower stool.
b_1 : Coefficient taken as:

$$b_1 = -0.20 + \frac{0.078}{R_{bt}}$$

b_1 = 0.13 for transverse bulkhead with no lower stool.
C_{m1} : Coefficient taken as:

$$C_{m1} = a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$$ but not taken less than 0.55.

$$C_{m1} = a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$$ for transverse bulkhead with no lower stool, but not taken less than 0.60

a_{m1} : Coefficient taken as:

$$a_{m1} = 0.63 + \frac{0.25}{R_{bt}}$$

$a_{m\,1}$ = 0.85 for transverse bulkhead with no lower stool.
b_{m1} : Coefficient taken as:

$$b_{m1} = -0.25 - \frac{0.11}{R_{bt}}$$

b_{m1} = 0.34 for transverse bulkhead with no lower stool.
C_3 : Coefficient taken as:

$$C_3 = a_3 + b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$$ but not taken less than 0.60.

$$C_3 = a_3 - b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$$ for longitudinal bulkhead with no lower stool, but not taken less than 0.55.

$a3$: Coefficient taken as:

$$a_3 = 0.86 - \frac{0.35}{R_{bl}}$$

a_3 =1.0 for longitudinal bulkhead with no lower stool.
b_3 : Coefficient taken as:

$$b_3 = -0.17 + \frac{0.10}{R_{bl}}$$

b_3 =0.13 for longitudinal bulkhead with no lower stool.
C_{m3} : Coefficient taken as:

$C_{m3} = a_{m3} + b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$ but not taken less than 0.55

$C_{m3} = a_{m3} - b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$ for longitudinal bulkhead with no lower stool, but not taken less than 0.60

a_{m3} : Coefficient taken as:

$$a_{m3} = 0.32 + \frac{0.24}{R_{bl}}$$

a_{m3} =0.85 for longitudinal bulkhead with no lower stool.

b_{m3} : Coefficient taken as:

$$b_{m3} = -0.12 - \frac{0.10}{R_{bl}}$$

b_{m3} =0.19 for longitudinal bulkhead with no lower stool.

R_{bt} : Coefficient taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 - \frac{b_{av-t}}{h_{st}}\right) \text{ for transverse bulkheads}$$

R_{bl} : Coefficient taken as:

$$R_{bl} = \frac{A_{bl}}{I_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 - \frac{b_{av-l}}{h_{sl}}\right) \text{for longitudinal bulkheads.}$$

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2.
A_{dt} = 0 if no upper stool is fitted.

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2.
A_{dl} = 0 if no upper stool is fitted.

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2.

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2.

b_{av-t} : Average width of transverse bulkhead lower stool, in m. See Figure 4.

b_{av-l} : Average width of longitudinal bulkhead lower stool, in m. See Figure 4.

h_{st} : Height of transverse bulkhead lower stool, in m. See Figure 4.

h_{sl} : Height of longitudinal bulkhead lower stool, in m. See Figure 4.

b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See Figure 4.

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

l_{ib} : Length of cargo tank at the inner bottom level between transverse lower stools, in m. See Figure 4.

l_{dk} : Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

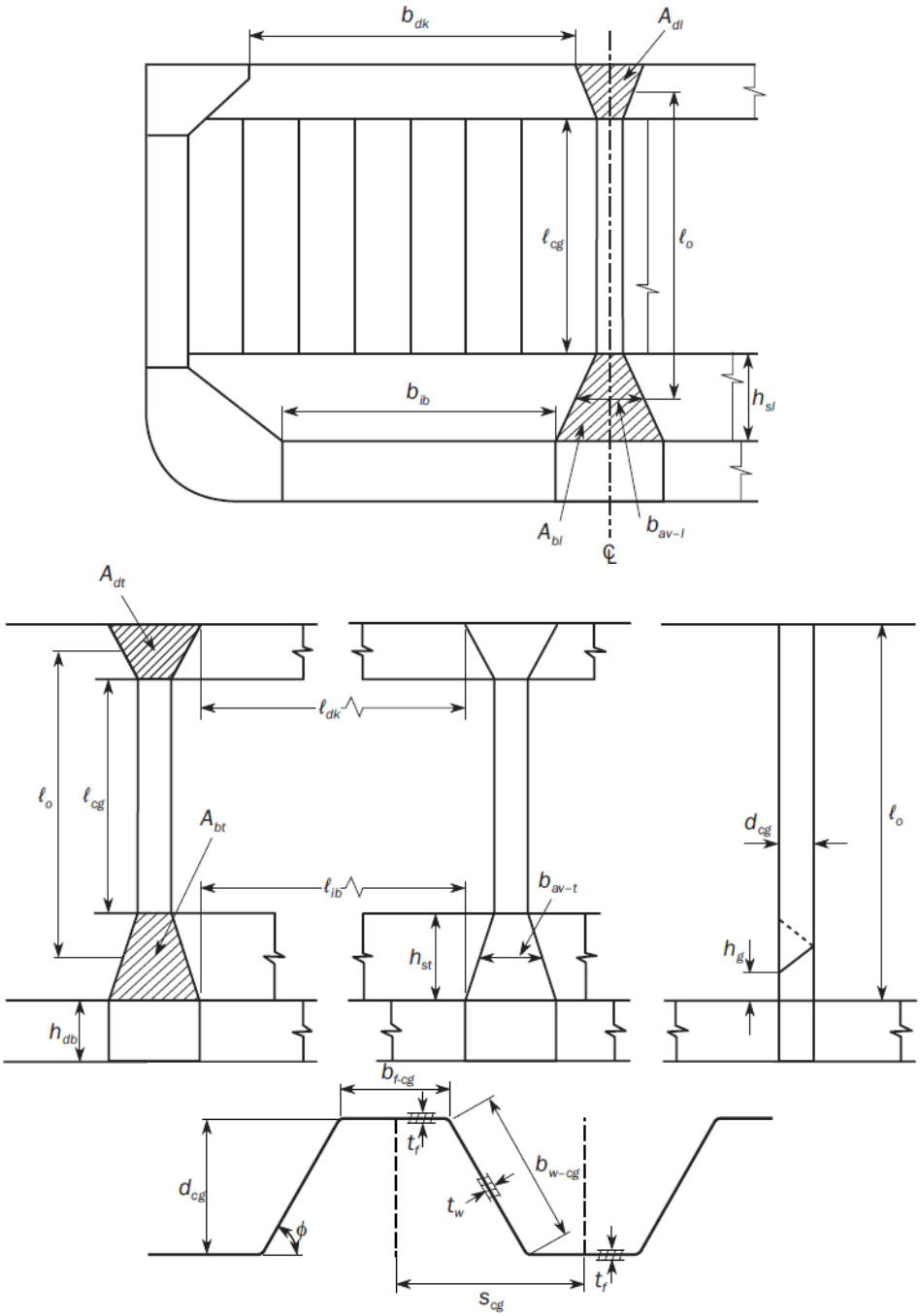


Figure 4 Definition of parameters for corrugated bulkhead (Tankers with longitudinal bulkhead at centreline)

SECTION 4 HULL OUTFITTING

1 SUPPORTING STRUCTURES FOR COMPONENTS USED IN EMERGENCY TOWING ARRANGEMENTS

1.1 General

1.1.1

It is the responsibility of the designer to provide emergency towing arrangements fitted at both the bow and stern of every tanker with a deadweight of 20,000 tonnes or more, as required by SOLAS, as amended.

1.1.2

The designer is reminded that design and construction of the towing arrangements are to be approved by the Flag Administration or the Society on their behalf.

1.2 Documents to be submitted

1.2.1

Plans showing details of the supporting structure for the emergency towing arrangement, including the connection to the deck, are to be provided for approval. Information on emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained is to be submitted for reference.

1.3 Structural arrangement

1.3.1 Continuity of strength

The structural arrangement is to provide continuity of strength.

1.3.2 Stress concentrations

The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

1.4 Minimum thickness requirements

1.4.1 Deck plating

The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15 mm.

1.5 Loads

1.5.1 Safe working loads

Safe working load of emergency towing arrangements is not to be taken less than:

- 1,000 kN for tankers having a deadweight greater than or equal to 20,000 t, but less than 50,000 t.
- 2,000 kN for tankers having a deadweight greater than or equal to 50,000 t.

1.5.2 Load case

The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the safe working load. Information on lines of action of the applied design load provided in emergency towing arrangement plan is to be taken into account.

1.6 Scantling requirements

1.6.1 General

The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in [1.5.2], the calculated stresses in the support structure do not exceed the permissible stress levels specified in [1.6.3].

The capacity of the structure to resist buckling failure is also to be assured.

1.6.2 Calculation procedure

These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two dimensional grillage or finite element analysis using gross scantlings.

1.6.3 Permissible stresses

For the design load given in [1.5.2], the shear stresses and normal stresses, including bending stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to be exceed the permissible values given below based on the gross thickness of the structure:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.58 R_{eH} .

Allowable buckling utilization factor is to be used as given in Ch 8, Sec 1, Table 1, for static and dynamic load scenario, S+D. Buckling assessment method is to be used according to Pt 1, Ch 8, Sec 4, [2].

2 MISCELLANEOUS DECK ATTACHMENTS

2.1 Cargo manifolds

2.1.1 Cargo manifold support

The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework into the ship structure in seagoing or in harbour operations during loading and unloading. To achieve this, the connection of the cargo manifold support to the deck is to be arranged to align with stiffening members of the main hull structure or stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

ISC 2.1.1a The connection structures of hull outfitting equipment to the deck are to comply with the requirements of ISC 6.1.1b in Section 4, Chapter 11 of PART 9-1.

3 GUARD RAILS AND BULWARKS

3.1 General

3.1.1

Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230 mm high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

3.1.2

Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100 mm surrounding the cargo deck. Along the sides at the aft end of the cargo deck of oil tankers, the coaming is to have a minimum height of 300 mm extending a minimum of 4.5 m forward from each corner. At the aft end of the cargo deck, the coaming is to have a minimum height of 300 mm and is to extend from side to side of the ship.

3.1.3

Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.

ISC Appendix A IACS REC.14 - HATCH COVER SECURING AND TIGHTNESS

(CORR.1 OCT. 2005)

1 Application

1.1

The following recommendations apply to steel hatch covers that are fitted to hatch openings on weather decks.

1.2

The recommendations, when relevant, also apply to the non-weathertight hatch covers which are accepted on container ships in accordance with the UI LL 64.

1.3

Where large relative movements between cover and ship structure or between cover elements are expected for ships having comparatively long/wide hatch ways, the application of these arrangements specified in the Recommendations for the gasket and securing arrangements are to be specially considered.

2 Design and Weathertightness

2.1 General

2.1.1

The weight of covers and any cargo stowed thereon, together with inertial forces generated by ship motions, are to be transmitted to the ship structure through suitable contact, such as continuous steel to steel contact of the cover skirt plate with the ship's structure or by means of defined bearing pads.

2.2 Weathertight Hatch Covers

2.2.1

The arrangement of weathertight hatch covers is to be such that weathertightness can be maintained in all sea conditions.

2.2.2

Weathertight sealings are to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and are to be made of a corrosion-resistant material.

2.2.3

The gasket material is to be of a quality suitable for all environmental conditions likely to be experienced by the ship, and is to be compatible with the cargoes carried. The material and form of gasket selected is to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between cover and ship structure. The gasket is to be effectively secured to the cover.

3 Drainage Arrangement

3.1 General

3.1.1

Drain openings are to be arranged at the ends of drain channels and are to be provided with effective means for preventing ingress of water from outside, such as non-return valves or equivalent.

3.2 Weather tight Hatch Covers

3.2.1

Drainage is to be arranged inside the line of gasket by means of a gutter bar or vertical extension

of the hatch side and end coaming.

3.2.2
Cross-joints of multi-panel covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

3.2.3
If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

4 Securing Devices

4.1 General

4.1.1
Devices used to secure hatch covers, i.e. bolts, wedges or similar, are to be suitably spaced along the coamings and between cover elements.

4.1.2
The minimum gross sectional area of each securing device is not to be less than:

$$A = \frac{1.4\bar{a}}{f} \quad \text{cm}^2$$

where:

$\bar{a}$ = *half the distance between the two adjacent securing devices, measured along hatch cover periphery, see Fig. 1, m*

$$f = (\sigma_F/235)^m$$

σ_F = *minimum upper yield stress of the material, not to be taken greater than 70% of the ultimate tensile strength, N/mm²*

m = 0.75 for σ_F *>235 N/mm²*

m = 1.00 for σ_F *α235 N/mm²*

Where the packing line pressure (see 4.2.2) exceeds 5 N/mm, the cross-sectional area of the securing devices is to be increased in direct proportion.

Rods or bolts are to have a minimum gross diameter not less than 19 mm for hatchways exceeding 5 m² in area.

4.1.3
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

4.1.4
Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

4.1.5
Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

4.2 Weathertight Hatch Covers

4.2.1
Arrangement and spacing of securing devices are to be determined with due attention to the effectiveness for weathertightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

4.2.2
Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices. The packing line pressure is to be specified.

4.2.3

The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The gross moment of inertia of edge elements is not to be less than:

$I = 6\,pa^4\ \ cm^4$

where:

p *= packing line pressure, with* $p \geqslant 5$ *N/mm*

a *= maximum of the distances,* a_i*, between two consecutive securing devices, measured along the hatch cover periphery (see Figure 1), not to be taken as less than 2.5* a_c*, m*

a_c *: max* $(a_{1.1}, a_{1.2})$ *, m*

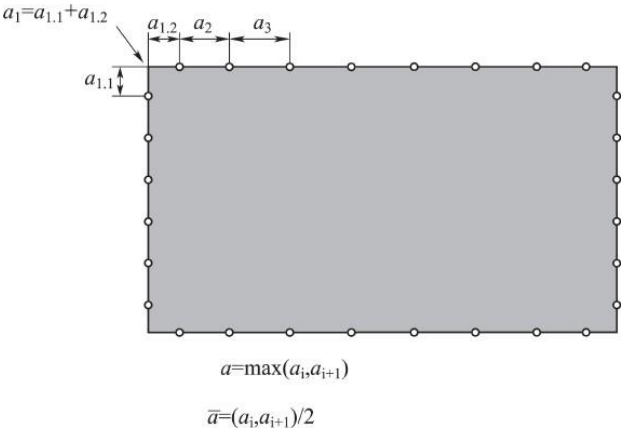


Figure 1 Distance between securing devices, measured along hatch cover periphery

When calculating the actual gross moment of inertia of the edge element, the effective breadth of the attached plating of the hatch cover, in m, is to be taken equal to the lesser of the following values:

- *0.165 a*
- *half the distance between the edge element and the adjacent primary member*

4.2.4

The angle section or equivalent section bearing the rubber seal is to be of adequate size and well integrated with the cover edge element structure to ensure uniform sealing pressure all along the line of contact

5 Securing Arrangement for Hatch Covers carrying Deck Cargo

5.1

In addition to the recommendations given in 4, all hatch covers, especially those carrying deck cargo are to be effectively secured against horizontal shifting due to the horizontal forces arising from ship motions.

5.2

To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and ship structure. The number should be as small as practically possible.

5.3

Considerations are to be given for assessment of cargo loads that towards the end of the ship vertical acceleration forces may exceed the gravity force. The resulting lifting forces must be considered when dimensioning the securing devices according to 4. Also lifting forces from cargo secured on the hatch cover during rolling are to be taken into account.

5.4

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

5.5

At cross-joints of multi-panel covers vertical guides (male/female) are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

5.6

In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for non-weathertight hatch covers may be omitted. In such cases, it is to be proven by means of grillage and/or finite element analyses that an equilibrium condition is achieved using compression-only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E above the hatch cover supports, where h_E must not be less than:

$h_E = 1.75(2se + d^2)^{0.5} - 0.75d$ *mm*

$h_{E,min}$ *= height of the cover edge plate +150 mm*

where:

e = largest distance from the inner edges of the transverse cover guides to the ends of the cover edge plate, mm

s = total clearance within the transverse cover guide, with $10 \leqslant s \leqslant 40$*, mm*

d = distance between upper edge of transverse stopper and hatch cover supports, mm

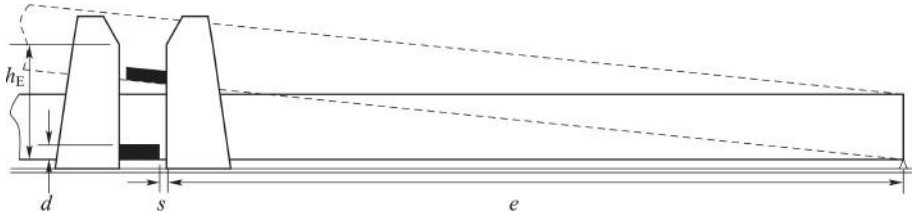


Figure 2 Height of transverse cover guides

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E and an allowable stress defined by each Classification Society.

6 Tightness Testing of Weathertight Hatch Covers

6.1

Upon completion of installation of hatch covers, a chalk test is to be carried out.

6.2

This is to be followed by a hose test with a pressure of water not less than 200 kN/m^2.

The following may be assumed for guidance:

Nozzle diameter: minimum 12 mm

Water pressure: sufficient for a free height of water with the stream directed upwards of 10 meters maximum

Distance to structure: maximum 1,5 meters

6.3

Alternative methods of tightness testing will be considered.

7 Operation Test

7.1

All hatch covers are to be operationally tested.

8 Operation and Maintenance

8.1

It is recommended that ships with steel hatch covers are supplied with an operation and maintenance manual including:

- *Operating and closing instructions*
- *Maintenance requirements for packings, securing devices and operating items*
- *Cleaning instructions for the drainage system*
- *Corrosion prevention instructions*
- *List of spare parts.*

ISC Appendix B IACS REC.34 - Standard Wave Data
(CORR. Nov. 2001)

1

This recommendation is valid for ships carrying goods at sea, excluding vessels that operate at a fixed location (for example FPSO s), specifically aiming at ships as covered by UR S11, and focusing on extreme wave loads.

2

Wave data as described by the scatter diagram given in TABLE 1, describe the wave data of the North Atlantic as defined in FIGURE 1, covering areas 8,9,15 and 16, as defined in Global Wave Statistics/1/ with changes according to /2/.

3

When calculating design wave bending moments, it is recommended to use a return period of at least 20 years, corresponding to about 10^{-8} probability of exceedance per cycle.

4

When calculating the pressure head from green seas on horizontal deck plates and hatch covers, the relative motion in the undisturbed wave at the centre line for the considered area, at a return period of 20 years, can be applied as a first approximation.

5

Combination of loads should be performed, preferably using simultaneous values, to ensure application of the design loads at a consistent probability level.

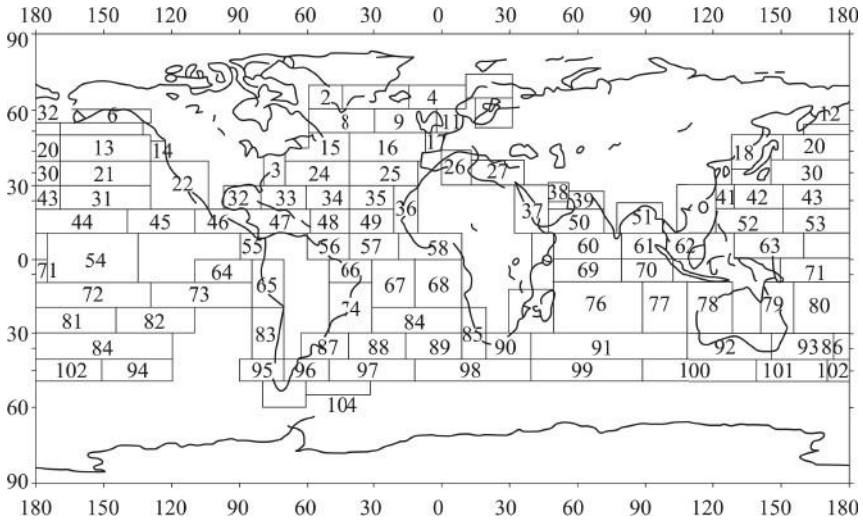


Figure 1 Definition of the extent of the North Atlantic

The Table 1 Probability of sea-states in the North Atlantic described as occurrence per 100000 observations.

Derived from BMT's Global Wave Statistics

Hs/Tz	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	SUM
0.5	0.0	0.0	1.3	133.7	865.6	1186.0	634.2	186.3	36.9	5.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3050
1.5	0.0	0.0	0.0	29.3	986.0	4976.0	7738.0	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0.0	0.0	0.0	22575
2.5	0.0	0.0	0.0	2.2	197.5	2158.8	6230.0	7449.5	4860.4	2066.0	644.5	160.2	33.7	6.3	1.1	0.2	0.0	0.0	23810
3.5	0.0	0.0	0.0	0.2	34.9	696.5	3226.5	5675.0	5099.1	2838.0	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0.0	19128
4.5	0.0	0.0	0.0	0.0	6.0	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0.0	13289
5.5	0.0	0.0	0.0	0.0	1.0	51.0	498.4	1602.9	2372.7	2008.3	1126.0	463.6	150.9	41.0	9.7	2.1	0.4	0.1	8328
6.5	0.0	0.0	0.0	0.0	0.2	12.6	167.0	690.3	1257.9	1268.6	825.9	386.8	140.8	42.2	10.9	2.5	0.5	0.1	4806
7.5	0.0	0.0	0.0	0.0	0.0	3.0	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1	2586
8.5	0.0	0.0	0.0	0.0	0.0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1	1309
9.5	0.0	0.0	0.0	0.0	0.0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	18.7	6.1	1.7	0.4	0.1	626
10.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4.0	1.2	0.3	0.1	285
11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1	124
12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	4.4	9.9	12.8	11.0	6.8	3.3	1.3	0.4	0.1	0.0	51
13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5	5.0	4.6	3.1	1.6	0.7	0.2	0.1	0.0	21
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0.0	0.0	8
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0.0	0.0	3
16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1
SUM:	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100000

The Hs and Tz values are class midpoints

6

For evaluation of extreme global bending moments it is recommended to use zero speed, provided the vessel does not have a service restriction, in which case the limitation should be checked as well. The effect of forward speed (2/3 of design speed) is recommended to be checked, especially for local dynamic pressures.

7

The Bretschneider or two parameter Pierson-Moskowitz spectrum is recommended for the North Atlantic, described by the following expression:

$$S(\omega) = \frac{H_S^2}{4\pi}(\frac{2\pi}{T_Z})^4 \omega^{-5} \exp(-\frac{1}{\pi}(\frac{2\pi}{T_Z})^4 \omega^{-4})$$

where:

H_s *= The significant wave height (m)*

ω *= Angular wave frequency (rad/s)*

T_Z *= The average zero up - crossing wave period (s)*

$$T_Z = 2\pi(\frac{m_2}{m_0})^{1/2}$$

The spectral moments of order n of the response process for a given heading may be described as

$$m_n = \int_\omega \sum_{\theta_0-90°}^{\theta_0+90°} f_s(\theta)\omega^n \cdot S(\omega / H_S, T_Z, \theta)\mathrm{d}\omega$$

using a spreading function usually defined as $f_s(\theta)=k\cos^2\theta$

where k is selected such that:

$$\sum_{\theta_0-90°}^{\theta_0+90°} f_s(\theta) = 1$$

where:

θ_0*=main wave heading*

θ*=relative spreading around the main wave heading*

8

In long term calculations, all wave headings (0-360°) can be assumed to have an equal probability of occurrence and at most 30°spacing between headings should be applied.

9

When calculating vertical bending moments (Sag and Hog) proper corrections for non-linear effects are to be applied.

10

The dynamic sea pressure can be derived above the mean waterline (WL) based on linear calculation methods by a reduction of 1-one meter pressure head per meter distance from the mean WL using a dynamic sea pressure at a return period of 20 years, corresponding to about 10^{-8} *probability per cycle. In case dynamic sea pressures at* 10^{-4} *probability per cycle are applied, a reduction of 1/2-half meter pressure head per meter distance above the mean WL should apply to ensure dynamic sea pressures at sufficient height above the mean WL.*

11

When calculating design sea pressures at ship ends, due consideration should be taken to the occurrence of non-linearity s such as slamming on the bottom and non-vertical ship sides.

References

/1/ British Marine Tec hnology (Primary contributors Hogben N., Da Cunha, L.F. and Oliver, H.N.). "Global Wave Statistics", Unwin Brothers Limited, London 1986.

/2/ Bitner-Gregersen, E.M., Cramer, E.H., Korbijin, F., "Environmental Description for Long-term Load Response of Ship Structures", ISOPE June 1995, The Hague, The Netherlands.



INTERNATIONAL SHIP CLASSIFICATION

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2024

PART TEN SHIPS IN RESTRICTED SERVICE

Table of Contents

CHAPTER 0 GENERAL 1

Section 1 GENERAL PROVISIONS 1

CHAPTER 1 SURVEYS AFTER CONSTRUCTION OF SHIPS ENGAGED ON NON-INTERNATIONAL VOYAGES 2

Section 1 GENERAL PROVISIONS 2

Section 2 HULL AND EQUIPMENT SURVEYS 2

Section 3 SURVEYS OF MACHINERY 16

Section 4 SURVEYS OF ELECTRICAL INSTALLATIONS 19

Section 5 INITIAL CLASSIFICATION SURVEY 20

Appendix 1 CORROSION AND WASTAGE CONTROL OF HULL STRUCTURE 24

Appendix 2 MINIMUM INSULATION RESISTANCE OF ELECTRICAL EQUIPMENT AND CIRCUITS IN HOT CONDITION 26

Appendix 3 MARKING OF LOAD LINES 27

CHAPTER 2 HULL 30

Section 1 GENERAL PROVISIONS 30

Section 2 SHIP TYPE REQUIREMENTS 32

CHAPTER 3 MACHINERY INSTALLATIONS 34

Section 1 GENERAL PROVISIONS 34

Section 2 MACHINERY INSTALLATIONS 34

CHAPTER 4 ELECTRICAL INSTALLATIONS 36

Section 1 MAIN SOURCE OF ELECTRICAL POWER 36

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER 36

Section 3 MISCELLANEOUS 37

CHAPTER 5 REFRIGERATED CARGO INSTALLATIONS 38

Section 1 GENERAL PROVISIONS 38

Section 2 REFRIGERATING PLANT 38

Section 3 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS 38

CHAPTER 6 FIRE PROTECTION, DETECTION AND EXTINCTION 39

Section 1 GENERAL REQUIREMENTS 39

CHAPTER 7 ADDITIONAL REQUIREMENTS 40

Section 1 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS 40

Section 2 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS 43

Section 3 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS 47

Section 4 DYNAMIC POSITIONING SYSTEMS 47

CHAPTER 0 GENERAL

Section 1 GENERAL PROVISIONS

0.1.1 Scope of application

0.1.1.1 The provisions of this PART apply to ships navigating and/or operating in restricted service, including ships engaged on international and non-international (domestic or regional) voyages and/or operation.

0.1.1.2 Where not covered by this PART, the relevant provisions of PART ONE to PART EIGHT of the Rules are to be complied with.

0.1.1.3 Where relevant provisions for ships engaged on non-international voyages in this PART are not consistent with the requirements of the Administration of the flag State, the requirements of the Administration of the flag State are to be satisfied and relevant requirements of this PART may not be satisfied.

0.1.2 Definitions

0.1.2.1 Restricted service is a generic term of the service categories 1, 2 and 3. For limitation for navigation of each service category, see Table 2.1.3.1, Section 1, Chapter 2, PART ONE of the Rules.

0.1.3 Class notations

0.1.3.1 Ships complying with this PART, except for the provisions for ships engaged on non-international voyages in restricted service, will be asssigned one of the following notations:

(1) Service category 1: R1;

(2) Service category 2: R2;

(3) Service category 3: R3.

0.1.3.2 Ships complying with the provisions for ships engaged on non-international voyages in restricted service of this PART will be suffixed D after the corresponding service category notations: R1(D), R2(D), R3(D).

0.1.3.3 For ships assigned with notations R1, R2, R3, the survey after construction is to comply with the relevant requirements of PART ONE of the Rules; for ships assigned with notations R1(D), R2(D), R3(D), the survey after construction is to comply with the relevant requirements of Chapter 1 of this PART.

0.1.3.4 For engineering ships whose operation areas are different from transiting areas, the areas applicable for transiting and operation may be identified separately, e.g.: R2 for Transiting and R3 for Operation.

0.1.3.5 Other service restriction or limitaton notations are given in Table C, Appendix 1, Chapter 2, PART ONE of the Rules.

CHAPTER 1 SURVEYS AFTER CONSTRUCTION OF SHIPS ENGAGED ON NON-INTERNATIONAL VOYAGES

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 For merchant ships rented or owned by the government and used for military purposes, special consideration may be given to the application of relevant requirements of this Chapter.

Section 2 HULL AND EQUIPMENT SURVEYS

1.2.1 General provisions

1.2.1.1 Unless provided otherwise, this Chapter applies to surveys of hull and equipment of all ships.

1.2.1.2 ISC will arrange an overall survey for the items related to the certificates, as appropriate, to confirm compliance with ISC rules.

1.2.1.3 Meetings for survey plans of oil tankers, bulk carriers and chemical tankers:

(1) The establishment of proper preparation and the close cooperation between the attending Surveyor(s) and the owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

(2) Prior to commencement of any part of the special survey, a survey planning meeting is to be held between the attending Surveyor(s), the owner's representative in attendance, the thickness measurement company operator (as applicable) and the master of the ship or an appropriately qualified representative appointed by the Company so as to ensure the safe and efficient conduct of the survey work to be carried out.

(3) The following is an indicative list of items that are to be addressed in the meeting:

① provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety);

② extent of the thickness measurements;

③ acceptance criteria;

④ extent of close-up survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion;

⑤ execution of thickness measurements;

⑥ taking representative readings in general and where uneven corrosion/pitting is found;

⑦ mapping of areas of substantial corrosion;

⑧ communication between attending Surveyor(s), the thickness measurement company operator(s) and owner's representative(s) concerning findings.

1.2.1.4 Documentation on board

(1) General requirements

① For oil tankers, bulk carriers and chemical tankers, the documentation specified in 1.2.1.4(2) is to be kept on board in the lifetime of the ship, which is to be readily available for the Surveyor.

② A thickness measurement report is to be a part of the documentation on board.

(2) Supporting documents

① The following additional documentation is to be available on board:

a. main structural plans of cargo oil and ballast tanks;

b. previous repair history;

c. cargo and ballast history;

d. inspection by ship's personnel with reference to:

i. structural deterioration in general;

ii. leakages in bulkheads and piping;

iii. condition of coating or corrosion protection, if any;

e. extent of use of inert gas plant and tank cleaning procedures (for oil tankers);

f. any other information that will help identify suspect areas requiring inspection.

1.2.1.5 The inspection of Watertight Cable Transits is to be carried out in accordance with Chapter 5,

PART ONE of the Rules.

1.2.2 Annual surveys

1.2.2.1 General requirements

(1) During the annual survey, conventional examinations are to be carried out by means of visual inspections and necessary tests to confirm whether the general condition of the ship is acceptable or whether the ship is under normal maintenance.

(2) Conventional external inspections and tests are specified so far as practicable in the items listed below.

1.2.2.2 The survey of all ships is to cover:

(1) Hull

① inspection of side shell and closing appliances above waterline;

② inspection of freeboard deck, weather deck and superstructure deck;

③ inspection and operational test of watertight doors on watertight bulkheads; Confirmation of closing appliance of shell plating opening below freeboard deck;

④ inspection of penetrations of watertight bulkheads, so far as practicable;

⑤ confirming, when appropriate and as far as is practicable when examining internal spaces on oil tankers and bulk carriers, that the means of access to cargo and other spaces remain in good condition;

⑥ examining cargo hold water level detectors and their audible and visual alarms on single skin &single-hold cargo ships;

⑦ confirming that no new installation of materials containing asbestos is on board.

(2) Protection of cargo hatches

① checking that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey;

② examining exposed hatch covers to confirm the structural integrity and capability of maintaining watertightness. Where extensive areas of wastage and/or substantial corrosion of steel hatch covers are found, thickness measurements are to be carried out to confirm the extent of wastage or corrosion, and renewals or repairs are required where wastage exceeds allowable margins;

③ where mechanically operated steel covers are fitted, checking the satisfactory condition of:

a. hatch covers including plating and stiffeners;
b. weathertight devices of covers (gaskets, gasket slots, drainage channels);
c. clamping devices, including bolts, cleating, retaining bars;
d. track wheels, guide rails, chains (or wires) and guide devices;
e. operating systems, including hydraulic systems and power units (if fitted).

④ where portable covers, wooden or steel pontoons (plus tarpaulin) are fitted, checking the satisfactory condition of:

a. wooden covers (including metallic end sheathing) and portable beams, carriers or sockets for the portable beams, and their securing devices;
b. steel pontoons, including chocks;
c. waterproof hatch cover tarpaulin (of at least 2 layers);
d. hatch compression bars and wedges;
e. cleats.

⑤ checking hatch coamings including deck connection, stiffeners, pillars, dunnage, wooden wedges;

⑥ checking draining non-return devices on hatch coamings.

(3) Protection of other openings

① examining flush scuttles, manholes, skylights and other watertight closing appliances;

② examining the circular openings of engine room casings, boiler casings and funnels, skylights, companionways on freeboard deck and weather deck, and boundary bulkheads, openings and weathertight closing appliances of deckhouse;

③ examining cargo hold hatches and other openings on weather deck, and coaming, closing and securing means thereon;

④ examining side scuttles and deadlights, windows, other openings and their closing devices;

⑤ examining ventilators including their closing appliances and flame screens, and air pipes and vents;

⑥ examining ends of enclosed superstructures;

⑦ examining all weathertight doors and their closing appliances of above spaces, including stiffeners, hinges and sealing devices; confirming operational condition of weathertight doors and their closing appliances.

(4) Discharges

① scuppers and sewage discharges with valves and controls on their pipelines;

② freeing ports and their protective bars and dampers.

(5) Suspect areas

① Suspect areas of the hull are to be examined, including those suspect areas which were identified at previous intermediate and/or special surveys. Where extensive areas of wastage are found, thickness measurements are to be carried out and renewals or repairs are required where wastage exceeds allowable margins.

(6) Steering gear

① general external examination of steering gear, accuracy of rudder angle indicator, and performance test.

(7) Anchoring equipment

① external examination of anchoring equipment for cracks, bending and twisting, loosening and detachment of stock, and secure connection to deck.

(8) Mooring equipment

① general external examination of mooring equipment.

(9) Fire safety

① confirming so far as practicable that no substantial change has been made to the fireproof structure and arrangement;

② operational test of manual and/or automatic fire doors (if fitted);

③ confirming that fire control plans are posted and kept as required;

④ testing of fire detectors and/or smoke detectors and alarms, so far as practicable;

⑤ examining fire pumps, hoses, nozzles and international shore connections, confirming that each fire pump, including the emergency fire pump, can by operated separately, and confirming that two jets of water are produced simultaneously from different hydrants at any part of the ship whilst the required pressure is maintained in the fire main;

⑥ checking the provision and randomly examining the condition of all portable and non-portable fire extinguishers, and checking appropriate maintenance information;

⑦ examining the fixed fire-fighting system for the machinery, cargo, vehicle, special category and ro-ro spaces, as appropriate, and confirming that its means of operation are clearly marked;

⑧ confirming that the fire fighter’s outfits and EEBDs are complete and in good condition and that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged;

⑨ confirming that the firefighters' outfits including its self-contained compressed air breathing apparatus and emergency escape breathing devices (EEBDs) are complete and in good condition, that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged, and that on board means of recharging breathing apparatus cylinders used during drills or a suitable number of spare cylinders to replace those used are provided, and for ships the keels of which are laid on or after 12 November 2016, provision of two-way portable radiotelephone apparatus of an explosion-proof type or intrinsically safe;

⑩ examining closing means of ventilators, funnels, skylights, doorways and shaft tunnels (if fitted);

⑪ examining the fire protection arrangements in cargo, vehicle and ro-ro spaces and confirming, as far as practicable and as appropriate, the operation of the means for closing the various openings;

⑫ examining, where appropriate, the special arrangements for carrying dangerous goods, including checking of the electrical equipment and wiring, the ventilation, the provision of protective clothing and portable appliances, and the testing of water supply, bilge pumping and any water spray system.

(10) Securing of containers

① examining securing fittings and means of containers.

1.2.2.3 In addition to the applicable requirements in 1.2.2.2, the following items are to be added for passenger ships (including ro-ro passenger ships and passenger ferries):

(1) The survey of watertight bulkheads and their arrangements is to:

① examine, so far as practicable, collision bulkhead and watertight bulkheads and confirm that their watertight integrity is not damaged;

② examine whether the diagram in the navigation bridge correctly shows the location of each watertight door and the OPEN/CLOSE indicators;

③ test the operation of locally or remotely controlled watertight doors, giving particular attention to audible and visual alarms activated on each side of the bulkhead and their operating mechanisms (if required or fitted);

④ confirm the operation of watertight doors after cutoff of main and emergency sources of power;

⑤ confirm that notices are posted at the appropriate places.

(2) The examination of shell openings is to include:

① closing appliances of side scuttles and deadlights, discharges, sewage drainages and similar openings as well as other water inlets and outlets below the margin line of shell;

② confirmation that side shell doors, cargo ports below the margin line can be effectively closed, and that the inboard end of cinder and garbage discharge chute is fitted with watertight seal;

③ general inspection of valves and pipelines of cross-flooding fittings, and operational test of remote control system.

(3) Verification that the emergency escape routes including related stairways and stairs in passenger and crew spaces are free from obstruction.

1.2.2.4 In addition to the applicable requirements in 1.2.2.2, the following items are to be added for oil tankers (including ore/bulk/oil carriers and ore/oil carriers) and chemical tankers:

(1) The examination of weather deck is to include:

① cargo tank openings including gaskets, covers, coamings and flame screens

② ventilation arrangement of cargo tanks, including overpressure/low pressure alarm (if fitted) and pressure/vacuum valves and flame screens;

③ flame screens on vents to all bunker, oily ballast, oily slop tanks and void spaces, so far as practicable;

④ cargo oil, crude oil washing, bunker, ballast and vent piping systems, including vent masts and headers.

(2) The examination of cargo pump rooms and pipe tunnels (if fitted) is to include:

① confirmation that no potential sources of ignition such as loose gear, excessive bilge accumulation, excessive vapour, combustible materials, etc., are present in or near the cargo pump room and that access ladders are in good condition;

② pump room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads;

③ performance test of bilge pumping system of pump room;

④ confirmation that the pump room ventilation system is operational, ducting intact, dampers operational and screens are clean.

1.2.2.5 In addition to the survey items in 1.2.2.2, the following items are to be added for ro-ro ships and other similar ships having bow doors (outer and inner doors), side shell doors and stern doors:

(1) verifying the doors and their surrounding structure;

(2) verifying the operation of doors and their dynamic devices;

(3) examination of sealing devices of doors, including airtight devices and related appliances;

(4) examination of locking and securing devices of doors;

(5) examination of local and/or remote controls of the locking/securing devices;

(6) examination of opening and closing of doors and associated securing attachments, such as wires, chains, track wheels, bars, guide plates and shackles;

(7) verifying tightness of doors;

(8) examination and testing of remote operating panel and associated indicator lights, television surveillance system, water leakage detectors, lighting and alarm system;

(9) examination of other necessary items and entries in logbook;

(10) verifying sewage disposal systems between inner and bow doors as well as in vehicle deck space;

(11) verifying that an approved operating and maintenance manual is available on board the ship.

1.2.3 Intermediate surveys

1.2.3.1 General requirements

(1) In addition to the applicable items specified for annual surveys in 1.2.2, intermediate surveys are to cover the structure of the ship to an extent sufficient for confirming good condition of the structure.

(2) Intermediate surveys are to be carried out in conjunction with surveys of the outside of the ship's bottom and related items in so far as practicable.

1.2.3.2 The scope of survey for all ships is to cover:

(1) Water ballast tanks

① For ships over 5 but less than or equal to 10 years of age, representative ballast tanks except for double bottom tanks are to be selected by the Surveyor for a general, internal examination. If there is no protective coating or any structural defect is found, the internal examination is to be extended to other water ballast tanks of the same type.

② For ships over 10 years of age, a general, internal examination of all salt water ballast tanks is to be carried out, and tightness test of inner bottom of cargo spaces within double bottom water ballast tanks is to be carried out.

(2) Cargo spaces

For ships over 15 years of age, at least 1 fore hold and 1 aft hold are to be selected by the Surveyor for internal examination.

(3) Thickness measurements

Where extensive areas of substantial corrosion are found, thickness measurements may be required and renewals are required where corrosion exceeds specified limits (see Appendix 1 of this Chapter).

(4) Examination of anchoring equipment

Partial test of slipping and hauling anchors by windlass.

(5) Fire-fighting equipment

Check of quantity and efficiency of medium of fixed fire-extinguishing arrangements, examination and testing of fire-extinguishing system.

1.2.3.3 In addition to the applicable requirements in 1.2.3.1 and 1.2.3.2, the following items are to be added for oil tankers (including ore/bulk/oil carriers and ore/oil carriers):

(1) The examination of weather deck is to include:

① cargo oil, crude oil washing, bunker, ballast, steam and vent piping systems, including vent masts and headers. Where deemed necessary by the Surveyor, pressure test or thickness measurement or both may be required for such piping systems.

(2) The examination of cargo piping is to include:

① cargo, crude oil washing, bunker, ballast, steam and vent piping systems on weather deck and in cargo pump room. If there is any doubt as to the condition of the piping, pressure test or thickness measurement or both may be required for such piping systems;

② cargo and stripping pumps including foundations, sealing, remote operation and quick-closing means;

③ confirmation that pressure gauges on cargo lines and level indicator systems are operational.

(3) Examination of cargo tanks

① For oil tankers of more than 10 years of age, the intermediate survey is also to include an internal examination of at least 3 cargo tanks located respectively at middle, port and starboard, if applicable.

② For oil tankers of more than 15 years of age, cargo tanks and ballast tanks may be pressure tested as appropriate.

1.2.4 Special surveys

1.2.4.1 General requirements

(1) Special surveys are to include examinations to an extent sufficient for confirming that the hull structure is in good condition and fit for the intended purpose.

(2) The examinations of the hull are to be supplemented by thickness measurements and testing as deemed necessary, to ensure that the structural integrity remains effective, and to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration.

(3) The owner is to provide the necessary facilities for a safe and efficient execution of the survey.

(4) The owner is to make preparations for survey according to the type and age of the ship and the items required for the special survey (including the extent of thickness measurements, necessary tests and compartments to be generally examined), and is to ensure:

① opening and cleaning of cargo holds, engine room, boiler room and other similar spaces including drainage channels, bilges and bilge wells, partial removal of wood sheathing (if required), derusting of steel plates and steel members;

② emptying, degassing and cleaning of double bottom tanks, topside tanks and deep tanks, derusting of rusted portions thereof and sufficient internal illumination therein.

(5) Special surveys are to include the items specified for intermediate and docking surveys in this Chapter. Docking surveys and relevant project surveys completed within the 15 months before the date due of special survey may be accepted as surveys simultaneous with special surveys.

1.2.4.2 The scope of survey for all ships is to cover:

(1) For all ships less than or equal to 5 years of age, the following items are to be additionally included:

① anchors and chain cables are to be pulled out, ranged and examined to verify their quantities and condition;

② all cargo holds, between decks, fore and aft peaks, engine and boiler rooms, cofferdams, decks and superstructures as well as other spaces are to be examined;

③ wood sheathing and other covering on deck and on inner bottom of holds are to be removed, as appropriate, to examine the steel structure thereunder;

④ examination of corners of large opening of holds, non-continuous structures, connection of stringer plates to sheer strakes;

⑤ thickness measurement of suspect areas, as required by the Surveyor;

⑥ masts, derrick posts, standing rigging, and derrick and windlass foundations are to be examined. Where extensive areas of wastage are found, thickness measurements are to be carried out and renewals or repairs are required where wastage exceeds allowable margins;

⑦ examination of hatch covers and coamings of holds:

a. an overall examination, according to the annual survey items listed in this Section, for determining wastage of steel plates, structural members, gaskets and locking devices. Where extensive areas of wastage are found, thickness measurements may be required and renewals are required where wastage exceeds allowable margins (see Appendix 1 of this Chapter). For hatch covers of the ships with reduced freeboard, particular attention is to be given to weathertightness and strength of hatch covers;

b. hatch covers of all holds are to be subject to hose testing or equivalent[①] for confirming watertightness of the covers;

⑧ internal examination of tanks:

a. in respect to peak tanks, double bottom tanks, topside tanks and hopper tanks used for water ballast, at least 1 representative tank of each type is to be selected for internal examination. Where extensive breakdown of protective coating is found, or where protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor;

b. overall examination of areas which are not coated or the coating of which has broken down, and no crack, excessive deformation and corrosion is allowed for structural skeleton, inner bottom, outer bottom, floors, girders and bulkheads. Attention is to be given to the plating of watertight bulkheads, floors, girders and the plating adjacent to heating coils in the fuel oil tank;

c. pipelines in tanks are to be examined, with attention being given to bent portions thereof. The wastage and technical condition of clamps, flanges, bolts, suctions and filters of pipelines and striking plate below all sounding pipes are also to be examined. Various valves of the pipelines are to be operationally tested, e.g. the collision bulkhead valve in fore peak. Attention is to be given to oil, water traces in cofferdams and if there are such traces, the cause of their existence is to be sought;

⑨ Tank test is to include:

a. boundaries of double-bottom tanks, deep tanks, water ballast tanks, and peak tanks used as liquid tanks and other tanks, including holds adapted for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds;

b. boundaries of fuel oil, lube oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries by the surveyor, and a confirmation that the pressure testing has been carried out according to the requirements with satisfactory results.

c. tanks are to be subject to hydraulic test after structural repairs affecting integrity.

(2) For ships over 5 but less than or equal to 10 years of age, in addition to the items listed in 1.2.4.2(1), the following items are to be included:

① all cargo holds, cofferdams, decks and superstructures are to be examined. In cases where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping,

---

① Small access opening covers may be verified by chalking.

and found sound and adhering satisfactorily to the steel;

② examination of anchoring equipment:

a. the anchors and chain cables are to be pulled out, cleaned, ranged and examined, and the weight of anchors is to be checked. Chain cables are to be gauged and if any length of chain cables is found to be reduced in mean diameter[①] at its most worn part by more than 15% from its nominal diameter as required, it is to be renewal;

b. the chain locker and its discharge means, holdfasts, hawse pipes, chain stoppers and windlass are to be examined and pumping arrangements of the chain locker are to be tested;

③ comprehensive internal examination of all water ballast spaces. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with.

(3) For ships over 10 years of age, in addition to the items listed in 1.2.4.2(1) and (2), the following items are to be included:

① the condition of air pipes, sounding pipes, steam pipes and other pipelines is to be examined;

② wood sheathing or other coverings on decks and linings of side scuttle are to be partially removed to inspect the steel plating thereunder;

③ examination of spaces used for water ballast:

a. for ships over 10 but less than or equal to 15 years of age, in addition to the requirements in (2) ③, at least 1 of the fuel oil tanks fitted with oil heating means is to be internally examined. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with;

b. for ships over 15 but less than or equal to 20 years of age, in addition to the requirements in (2) ③a, at least 2 of the fuel oil tanks fitted with oil heating means are to be internally examined. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with;

c. for ships over 20 years of age, all tanks (including oil tanks, water tanks and voids) are to be subject to external examination, hydraulic test and internal examination.

④ At special survey No.3 and subsequent special surveys, structural downflooding ducts and structural ventilation ducts are to be internally examined.

(4) Extent of thickness measurement:

① Unless expressly provided otherwise, minimum requirements for thickness measurements of ships are given in Table 1.2.4.2(4)①.

Minimum Requirements for Thickness Measurements at Special Surveys of Ships Other Than Otherwise Expressly Provided Table 1.2.4.2(4)①)

Age ≤ 15	15 < Age ≤ 20	Age >20
a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas
	b Wind and water strakes at each side, and at least 2 points on each strake of strength deck beyond line of openings, within amidships 0.5L	b Wind and water strakes at each side, and at least 2 points on each strake of strength deck beyond line of openings, within amidships 0.5L
	c Shell and deck plating, longitudinal and transverse members in one transverse section, within amidships 0.5L	c Shell and deck plating, longitudinal and transverse members in two transverse sections of different holds, within amidships 0.5L; only 1 section to be measured for ships less than 100 m in length

② Thickness measurements are normally to be carried out by a ISC-approved company. The required thickness measurements, if not carried out by ISC itself, are to be witnessed by an attending Surveyor of ISC. The measurement is to be done by means of drilling or ultrasonic test equipment. The accuracy of the equipment is to be confirmed by the Surveyor as satisfactory. The test personnel are to hold a qualification certificate acceptable to ISC. A thickness measurement report is to be prepared to indicate measurement positions, thicknesses measured, corresponding initial thicknesses

① The mean diameter is half the value of the sum of the minimum diameter found in one cross section of the link and of the diameter measured in a perpendicular direction in the same cross section.

and maximum allowable diminution, and date of measurement, type of measurement equipment as well as expiry date of test, name of measurer and qualification. The surveyor is to review the final thickness measurement report and countersign on the cover. The surveyor may sample the measurement results.

③ Thickness measurements may be carried out at the commencement of the special survey, or the thickness measurement report prepared within 15 months before the due date of the special survey may be taken as the thickness measurement report of the special survey.

④ The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine areas of substantial corrosion. Table 1.2.4.2(4)② may be used as guidance for the additional thickness measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.

Guidance for Additional Thickness Measurements in Way of Substantial Corrosion

Table 1.2.4.2(4)②

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5-point pattern over 1 square meter
Stiffeners	Suspect area	3 measurements each in line across web and flange

1.2.4.3 The additional survey scope of passenger ships and ro-ro passenger ships may cover:

(1) Lightweight survey for verification of light displacement and the change of longitudinal centre of gravity. Where the deviation of lightweight exceeds 2% or the deviation of longitudinal center of gravity exceeds 1% L[①], the inclining test is to be carried out again.

(2) The extent of thickness measurements of passenger ships and ro-ro passenger ships is given in Table 1.2.4.3(2).

Minimum Requirements for Thickness Measurements at Special Surveys of Passenger Ships, Ro-Ro Passenger Ships

Table 1.2.4.3(2)

Age ≤ 5	5 < Age ≤ 20	10 < Age ≤ 15	Age >15
a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas throughout the ship
	b One transverse section of deck within amidships 0.5L	b Two transverse sections of deck of different ballast tanks, within amidships 0.5L	b Transverse sections of deck of at least three ballast tanks, within amidships 0.5L
	c Wind and water strakes	c Internals in fore peak ballast tank	c Internals in fore and aft peak ballast tanks
		d Wind and water strakes	d All exposed main deck and vehicle deck, full length
			e Representative exposed superstructure deck
			f All wind and water strakes, port and starboard, full length
			g All keel plates, full length. Also, additional bottom plates in way of aft end of tanks and machinery space
			h Bow, stern and side shell doors used as vehicle ramps

1.2.4.4 Supplementary requirements for oil tankers (including double hull oil carriers):

(1) General requirements:

① Items of special surveys of "all ships" in this chapter are to be included.

② Cargo piping on deck, including crude oil washing (COW) piping, cargo and ballast piping within all cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and

① *L* refers to the length defined by regulation 3 of the Load Line Convention.

void spaces bounding cargo tanks are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally

③ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions (lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.) of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined.

② A ballast tank is to be examined at subsequent annual intervals where:

a. a hard protective coating has not been applied from the time of construction, or

b. a soft or semi-hard coating has been applied, or

c. substantial corrosion is found within the tank, or

d. the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(3) Extent of overall surveys

① For oil carriers (including double hull oil carriers) of 12 years and more in age, an overall survey of all tanks and spaces is to be carried out at each special survey.

② The Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

a. in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;

b. in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) Scope of thickness measurement

① At special surveys, the minimum requirements for thickness measurement are listed in Table 1.2.4.4(4) ①.

② The increased extent of thickness measurements for substantial corrosion is to be in accordance with the relevant requirements for "all ships". These extended thickness measurements are to be carried out before the survey is credited as complete. Suspect areas identified at previous surveys are to be examined; Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurements according to Table 1.2.4.4(4) ① may be specially considered.

⑤ Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

⑥ In cases where two or three sections are to be measured, at least one is to include a ballast tank within 0.5*L* amidships.

Minimum Requirements for Thickness Measurements at Special Surveys of Oil Tankers (including double hull oil tankers), Ore/ Oil Ships, etc.

Table 1.2.4.4(4) ①

Age ≤ 10	10 < Age ≤ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 In cargo areas: a) each deck plate; b) two transverse sections; c) all wind and water strakes	2 In cargo areas: a) each deck plate; b) three transverse sections; c) each bottom plate
	3 Selected wind and water strakes outside the cargo area	3 For combination carriers, all hatch covers and hatch coamings (plate and stiffener) of all cargo holds

Age ≤ 10	10 < Age ≤ 15	Age > 15
		4 Internals in forepeak and afterpeak ballast tanks
		5 All exposed main deck full length
		6 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		7 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8 All wind- and water strakes, port and starboard, full length
		9 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

(5) Extent of tank testing

① The minimum requirements for ballast tank testing are given in ③ of this paragraph and Table 1.2.4.4(5)①; the minimum requirements for cargo tank testing are given in ④ of this paragraph and Table 1.2.4.4(5)①. Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

a. a tank testing procedure has been submitted by the Owner and reviewed by ISC prior to the testing being carried out;

b. there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

c. the cargo tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;

d. the satisfactory results of the testing is recorded in the ship's logbook;

e. the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

⑤ For double hull oil tankers, the testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

⑥ Tanks may be pressure tested while the ship is afloat provided that their internal examination is also carried out while the ship is afloat.

Minimum Requirements for Tank Testing at Special Surveys of Oil Tankers (including double hull oil tankers), Ore/ Oil Ships, etc.

Table 1.2.4.4(5) ①

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries 2. All cargo tank bulkheads

(6) Examination of emergency towing arrangements (if fitted):

① Confirming that strong points, towing pennants, towing connection, pick-up gear, chafing gear and mark buoys are in good and efficient condition.

② Verifying that wear of towing pennant, pick-up gear and chafing gear is under permissible limits.

③ Verifying that fairleads are maintained in a normal condition as required.

(7) The availability and normal maintenance of bow and stern loading/unloading arrangements (if fitted) are to be verified.

1.2.4.5 Additional requirements for bulk carriers (including double skin bulk carriers):

(1) General requirements:

① Items of special surveys of "all ships" in this Chapter are to be included;

② All piping systems (or ballast piping systems in the case of double skin bulk carriers) within the above spaces are to be examined and operationally tested in working condition to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

③ The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.

④ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks (Note: Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line) are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

② When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

③ Where a hard protective coating is provided in cargo holds also used as salt water ballast and is found in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

(3) Hatch covers and coamings:

① Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:

a. stowage and securing in open condition;

b. proper fit and efficiency of sealing in closed condition;

c. operational testing of hydraulic and power components, wires, chains, and link drives.

② Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.

③ Thickness measurement of the hatch cover and coaming plating and stiffeners is to be carried out for bulk carriers and double skin bulk carriers as given in Table 1.2.4.5(5)①.

(4) Extent of overall surveys

① For bulk carriers (including double skin bulk carriers) of 18 years and over in age, an overall survey of all tanks and spaces is to be carried out at each special survey.

② The Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

(5) Extent of thickness measurement

① The minimum requirements for thickness measurement at special survey are given in Table 1.2.4.5(5)① for bulk carriers and double skin bulk carriers.

② Extended measurements for areas with substantial corrosion are in accordance with the relevant provisions for "all ships". These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurement according to Table 1.2.4.5(5) ① may be specially considered.

⑤ Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements.

Minimum Requirements for Thickness Measurements at Hull Special Surveys of Bulk Carriers (including double skin bulk carriers)

Table 1.2.4.5(5) ①

Age ⩽ 10	10 < Age ⩽ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Two transverse sections, one in the amidship area, outside line of cargo hatch opening. c. All wind and water strakes	2 Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Three transverse sections, one in the amidship area, outside line of cargo hatch opening. c. Each bottom plate
	3 Selected wind and water strakes outside the cargo length area	3 All hatch covers and hatch coamings (plate and stiffener) of all cargo holds
		4 Internals in forepeak and afterpeak ballast tanks
		5 All exposed main deck full length
		6 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		7 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8 All wind- and water strakes, port and starboard, full length
		9 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

(6) Extent of tank testing

① All boundaries of water ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, only representative tanks are to be pressure tested.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of holds jointly used as sea water ballast are to be tested with a head of liquid to near to the top of hatches.

⑤ The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

1.2.4.6 Additional requirements for chemical tankers:

(1) General requirements:

① Items of special surveys of “all ships” in this Chapter are to be included.

② Cargo piping on deck and cargo and ballast piping within the above tanks and spaces are to be examined and operationally tested to working pressure to attending Surveyor’s satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be

advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally.

③ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks (Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.) are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:

a. a hard protective coating has not been applied from the time of construction, or
b. a soft or semi-hard coating has been applied, or
c. substantial corrosion is found within the tank, or
d. the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(3) Extent of overall surveys

① For chemical tankers of 12 years and over in age, an overall survey of all tanks and spaces is to be carried out at each special survey. The survey of stainless steel tanks may be carried out as an overall survey supplemented by close-up survey as deemed necessary by the surveyor..

② The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

a. in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;
b. in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) Extent of thickness measurement

① The minimum requirements for thickness measurement are given in Table 1.2.4.6(4) ①. Thickness measurement of stainless steel hull structure and piping may be waived, except for clad steel plating.

Minimum Requirements for Thickness Measurements at Special Surveys of Chemical Tankers

Table 1.2.4.6(4) ①

Age ⩽ 10	10 < Age ⩽ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 Within the cargo area: a) each deck plate; b) two transverse sections; c) all wind and water strakes	2 Within the cargo area: a) each deck plate; b) three transverse sections; c) each bottom plate
	3 Selected wind and water strakes outside the cargo area	3 Internals in forepeak and afterpeak ballast tanks
		4 All exposed main deck full length
		5 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		6 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		7 All wind- and water strakes, port and starboard, full length
		8 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		9 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

② Extended measurements for areas with substantial corrosion are in accordance with the relevant provisions for "all ships". These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurement according to Table 1.2.4.6(4) ① may be specially considered.

⑤ Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements.

⑥ In cases where two or three sections are to be measured, at least one is to include a ballast tank within 0.5*L* amidships.

(5) Extent of tank testing

① The minimum requirements for ballast tank testing are given in ③ of this paragraph and Table 1.2.4.6(5)①; the minimum requirements for cargo tank testing are given in ④ of this paragraph and Table 1.2.4.6(5) ① . Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

a. a tank testing procedure has been submitted by the Owner and reviewed by ISC prior to the testing being carried out;

b. there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

c. the tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;

d. the satisfactory results of the testing is recorded in the ship's logbook;

e. the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

⑤ The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

⑥ Tanks may be pressure tested while the ship is afloat provided that their internal examination is also carried out while the ship is afloat.

Minimum Requirements to Tank Testing at Special Survey of Chemical Tankers

Table 1.2.4.6(5) ①

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries. 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries. 2. All cargo tank bulkheads

(6) Chemical tankers over 10 years in age

① Selected steel cargo pipes outside cargo tanks and ballast pipes passing through cargo tanks are to be:

a. thickness measured at random or selected pipe lengths to be opened for internal inspection;

b. pressure tested to the maximum working pressure.

Special attention is to be given to cargo/slop discharge piping through ballast tanks and void spaces.

1.2.4.7 Additional thickness measurement requirements for ships of 35 years and over in age:

(1) Ship length L≥65m: measure 3 transverse sections, among which one is within amidships 0.5L; ship length L＜65m: measure 2 transverse sections;

(2) Internals in forepeak and afterpeak tanks;

(3) All exposed main deck full length;

(4) Representative exposed superstructure deck;

(5) All wind- and water strakes, port and starboard, full length;

(6) All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks;
(7) Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor.

Section 3 SURVEYS OF MACHINERY

1.3.1 General provisions

1.3.1.1 Unless provided otherwise, the requirements of this Section apply to machinery surveys of all ships after construction.
1.3.1.2 For ships with machinery automation notations, the machinery installations are to comply with the requirements of 5.9.4.4, Chapter 5, PART ONE of the Rules.
1.3.1.3 The owner or manager of the ship is to make preparations for survey according to the type and items of survey, e.g. cleaning of parts to be dismantled, availability of drawings, information, certificates and reports needed for survey, safe access to survey location and safety facilities.
1.3.1.4 Machinery surveys are generally to be carried out in conjunction with corresponding hull surveys.

1.3.2 Annual surveys

1.3.2.1 General requirements
(1) Machineries and boilers are normally not required to be opened up during annual surveys, and sufficient items may be examined in working condition. Locations of machinery and shafting are to be examined to confirm their satisfactory condition, including interview of related crew members on service of main machineries and if necessary, check of engine room logbook and measurement records, etc.
1.3.2.2 Survey items
(1) General examination of machinery and boiler spaces, in particular examining the means for the operation of the main and auxiliary machinery essential for the propulsion and the safety of the ship, including, when applicable, the means of remotely controlling the propulsion machinery from the navigating bridge (including the control, monitoring, reporting, alert and safety actions) and the arrangements to operate the main and other machinery from a machinery control room, confirming that there is no existence of any fire and explosion hazards, particularly in way of inner bottom and bilge wells and that moving parts and hot surfaces will not injure personnel.
(2) Verification that escape routes in machinery spaces are free from obstruction.
(3) Testing of the means of communication between the navigation bridge and machinery control rooms, steering gear compartment and where fitted, emergency steering positions.
(4) Examination of the bilge pumping systems and bilge wells, including operation of pumps and where fitted, level alarms, as far as practicable; operational testing of emergency bilge pumping systems of passenger ships.
(5) External examination of all accessible parts of the main and auxiliary steering gears.
(6) Action test of remote closing valves of fuel oil and lubricating oil tanks.
(7) Performance test and closing and shutoff tests are to be carried out from outside the machinery space for fans, remote oil pump cutoff devices in the engine room.
(8) General examination of dynamic positioning system or side thrust system onboard.
(9) Confirmation of implementation of planned maintenance scheme, if applicable.
1.3.2.3 For oil tankers, in addition to the requirements of 1.3.2.2, cargo oil pump room, pump room bilge system, ventilation system of cargo oil pump room and associated equipment are to be generally inspected and safety alarm system, if fitted, operationally tested.

1.3.3 Intermediate surveys

1.3.3.1 Survey items
(1) The items in 1.3.2.2 of this Chapter applicable to the ship.
(2) Prime movers of driving generators are to be operationally tested under working conditions to verify that they are in a good working condition.
(3) When the ship is in dock, all openings and valves of machinery spaces and pump rooms at the ship's side together with their fasteners connected to the shell plating are to be examined.

1.3.4 Special surveys

1.3.4.1 Survey items

(1) The items in 1.3.3.1 of this Chapter applicable to the ship.
(2) When the ship is in dock, all sea connection openings, including sewage discharges and other overboard discharges, together with valves and fasteners on the shell plating, are to be examined internally and externally.
(3) Pumps and pumping systems, including valves, cocks, pipes and filters, are to be examined. Nonmetallic hose expansion pieces of the main circulating system are to be examined. Bilge system is to be confirmed in good condition and if deemed necessary, other systems are to be operationally tested.
(4) Thrust shaft and intermediate shaft and their bearings are to be opened up for examination.
(5) Foundations (including foundation bolts and packing blocks) of main and auxiliary engines are to be examined.
(6) All shafts (excluding screwshaft, tubeshaft, directional propeller and water jet propulsion arrangements) and bearings of the main propulsion system are to be examined. The lower half of the bearings may be sampled if crankshaft deflection of the main engine and wear of bearings are found in order.
(7) Heat exchangers and other non-burner pressure vessels with working pressures over 0.7 MPa are to be opened up and examined and where deemed necessary, pressure tested, and associated relief valves are to be checked; the evaporator of the casing need not be opened up and acceptance may be based on satisfactory external examination and operation record review.
(8) Air compressors, air receivers with associated pipes are to be examined; if the internal examination of air receivers is impracticable, this may be replaced by hydraulic test; the working condition of relief valves and safety devices is to be examined.
(9) Examination of steering arrangements, including operational test and check of relief valve setting, is to be carried out. A hydraulic test may be performed by using the power of the steering system to set the relief valve.
(10) Where necessary, gearboxes are to be opened up and examined to confirm the condition of pinions and wheels, shafts, bearings, and lubricating system. For conventional gear units of 1,120 kW and below and all epicyclic gear units, where the shipowner can provide satisfactory operation records, then they may not necessarily be opened for examination.
(11) Examination of windlass, including operational check, check of the brake and testing of safety devices, is to be carried out.
(12) For diesel engines including main and auxiliary engines, the following parts (if fitted) are to be disassembled or opened up for examination:

① cylinders, cylinder liners, cylinder covers, valves and their transmitting gear;
② high pressure oil pumps, scavenging pumps and superchargers;
③ pistons, crossheads, connecting rods;
④ crankshafts including crankpins and bearings, main journals and associated bearings;
⑤ reverse gears, air compressors and intercoolers;
⑥ retightening of stay bolts as necessary, tightness check of bolts of frames and entablatures;
⑦ measurement of crankshaft deflection of engines having a speed of 300 r/m or below;
⑧ examination of all parts. However, those parts which need not be re-examined in 15 months may be specially considered;
⑨ the survey of diesel engines with bores of 300 mm or below may be replaced by review of maintenance records, including records of lubrication servicing, provided that such engines are maintained according to the manufacturer’s scheduled maintenance program;
⑩ essential components of the oil fuel system of diesel engines, including oil separator, oil fuel servicing pump and heater are to be opened up and examined.

(13) Electric propulsion plant: see relevant requirements of Section 4 of this Chapter.
(14) For steam turbines including main and auxiliary turbines, the following parts are to be opened out for examination:

① rotor with blading and shrouding and bearings;
② nozzles, stationary blading, interstage packing and gland seals with oil barriers;
③ bleed controls and foundation expansion arrangements;
④ throttle valves are to be operationally tested and opened up for examination as deemed necessary.

In general, lifting of the main propulsion turbine casing may be waived for new-installed ones within 5 years, provided the turbines are fitted with rotor position indicators and vibration indicators of an approved type, as well as steam pressure measuring equipment at appropriate locations in the steam flow path. Rotor bearings, thrust bearings and the flexible coupling are to be opened and examined. The low pressure turbine

exhaust trunk is to be opened for examination of the last row of low pressure and astern wheels. Turbine operating records are to be reviewed. The arrangements for changeover in case of emergency operation of the plant are to be readily available. The turbines are to be operationally tested.

Turbine casings are to be lifted for confirming the effectiveness of the maintenance arrangement at the special survey after 10 years. However, the lifting of main propulsion turbine casings may be waived at the special survey after 15 years and subsequent special surveys, provided that:

a. an approved preventative maintenance arrangement has been established, including vibration monitoring, lubricating oil analysis and rotor position checks;
b. the rotor journal bearings, thrust bearings and flexible couplings are opened up for examination, the low-pressure turbine exhaust trunk is opened for examination of the last row of low pressure and astern wheels;
c. the turbine operating records are reviewed and all considered satisfactory by the Surveyor, at least in compliance with the manufacturere recommendations;
d. the turbines are to be operationally tested.

(15) For gas turbines, the followings are to be opened out for examination:

① Gas turbines are to be opened up and maintained in accordance with the manufacturer's recommendations. For each type of turbines, the owner is to submit maintenance schedules for checking combustion, hot-gas-path and other items as specified in proposed service intervals.

② For units in continuous service, at least one hot-gas-path examination is to be scheduled each survey period, including examining turbine rotors, nozzles (fixed blading), combustors, inlet casings, exhaust casings, air control valves and protective apparatus. Other parts and associated equipment are to be examined as necessary.

③ Opening of compressor sections can be scheduled in conjunction with other items, provided that examination of the blades visible from the inlet plenum during the hot-gas-path examination reveals no evidence of defects.

④ The required examinations of auxiliary gas turbine units, at least once each period, are to be based on manufacturer's recommendations, as appropriate for the actual operating hours and conditions, together with an operation test including protective apparatus.

Where units are arranged such that the unit is removed from the vessel and dismantled at another facility, the internal examination may be carried out at the facility. The reinstallation is to be carried out to the satisfaction of the Surveyor.

Upon reassembly/reinstallation, all fuel lines, lube oil piping, the unit itself and exhaust system are to be checked under full speed operational conditions for leakage. All shielding and fuel oil double wall piping is to be examined.

⑤ Cylinders, pistons, end covers, valves and valve gear, pumps and fittings, synchronizing and control gear, cooling system, explosion relief devices including bypass arrangements of free piston gas generators are to be opened out and examined.

⑥ Air compressors of gas generator in combustion chamber, including rotors and casings, combustion chambers, burners, intercoolers, heat exchangers, gas and air piping of gas turbines are to be opened out and examined.

1.3.4.2 As part of the Special Survey of Machinery, a dock trial is to be carried out to attending Surveyors' satisfaction to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration should be given to carrying out a sea trial to attending Surveyors' satisfaction.

1.3.4.3 If the significant repairs as stated in 1.3.4.2, is considered by ISC to have any impact on response characteristics of the propulsion systems, then the scope of sea trial is also to include a test plan for astern response characteristics based on those required for such an equipment or systems when fitted to the new ship. Refer to 1.2.4, Chapter 1, PART THREE of the Rules for astern testing requirements.

The tests are to demonstrate the satisfactory operation of the equipment or system under realistic service conditions at least over the manoeuvring range of the propulsion plant, for both ahead and astern directions. Depending on the actual extent of the repair, ISC may accept a reduction of the test plan.

1.3.5 Surveys of propeller shafts and tube shafts

1.3.5.1 Relevant requirements for surveys of propeller shafts and tube shafts are given in Section 12, Chapter 5, PART ONE of the rules.

Section 4 SURVEYS OF ELECTRICAL INSTALLATIONS

1.4.1 General requirements

1.4.1.1 This Section applies to surveys of electrical installations for all ships after construction.

1.4.2 Annual surveys

1.4.2.1 Survey items

(1) Operational test of the means of communication between the navigation bridge and machinery control stations, steering gear compartment and where fitted, emergency steering positions.

(2) General examination of the electrical equipment and cables forming the main and emergency electrical installations in working condition, so far as practicable.

(3) Confirming that main power source, emergency power source (including the standby power source equivalent to the emergency power source), the electrical equipment essential to safety in an emergency, e.g. emergency lighting, general emergency alarm system, are in good working condition. Where these power sources are automatically controlled, the test is to be carried out in automatic mode.

(4) Examination of bonding straps for the control of static electricity and earthing arrangements where fitted.

(5) General examination of control systems and associated machinery of electric propulsion plant, dynamic positioning system and/or auxiliary thrusters of position-keeping mooring system.

(6) Confirming that motors driving the pumps serving main propulsion machinery and auxiliary machineries together with controls are in good condition.

(7) Confirming voyage repairs made by crew.

(8) Confirming that the electrical equipment installed in areas where flammable gas or vapour and/or flammable dust may accumulate is in good condition and well maintained.

(9) Confirming that no potential sources of ignition (e.g. no loose gear, excessive bilge oil or oily vapour) exist in cargo oil pump rooms of oil tankers.

(10) Where the electrical distribution system on board a ship includes harmonic filters, the total harmonic distortion (THD) recorded onboard the ship is to be checked.

1.4.3 Intermediate surveys

1.4.3.1 Survey items

(1) The applicable items in 1.4.2 of this Chapter;

(2) For oil tankers:

① electrical equipment an cables in dangerous zones are to be examined to confirm that there are no defective, improperly installed equipment and dead end wiring;

② insulation resistance of electrical circuits terminated in or passing through dangerous zones is to be tested (see Appendix 2 of this Chapter). Where spaces are not gas-freed, the existing record of testing may be accepted.

1.4.4 Special surveys

1.4.4.1 General requirements

(1) The owner is to provide the necessary conditions and safety facilities for the survey, e.g. disassembling or opening and cleaning, safe access to and illumination for survey items.

1.4.4.2 Survey and test items

(1) The applicable items in 1.4.3 of this Chapter.

(2) Insulation resistance of electrical equipment and circuits are to be tested.

(3) The fittings on the main switchboard, emergency switchboard (including emergency battery charging and discharging panel), section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

(4) Circuit breakers of generators are to be tested, so far as possible, to confirm that protective devices including preferential trip relay (if fitted) are in good working condition.

(5) Cables are to be examined without damaging their fasteners or protective casings so far as possible, except when they are to be opened up as deemed necessary upon examination or test results of (2).

(6) Motors and their auxiliary control and switch gear for essential services are to be examined, and tested operationally in working condition so far as possible. All generators and steering motors are to be examined and tested in working condition. However, they need not be tested at the rated load test or simultaneously.

(7) Where transformers of essential power supply are of wet type, the owner is to submit the liquid sample to an authoritative institution for testing its breakdown voltage, acidity and moisture. The report of test results is to be submitted to the Surveyor.
(8) Emergency power source (including the standby power source equivalent to the emergency power source) together with its automatic control gear and associated circuits are to be tested.
(9) Emergency lighting, temporary emergency lighting, supplementary emergency lighting (if fitted) and general emergency alarm system are to be tested in so far as practicable.
(10) For electrically propelled ships, the propulsion motors, generators, cables and all ancillary electrical equipment, exciters and associated ventilators (including coolers) are to be examined and their insulation resistance relative to earth tested. Particular attention is to be given to examination of windings, commutators and slip rings. Protective devices and alarms are to be operationally examined as far as possible. Where insulating oil is used, the test is to comply with provisions of (7). Interlocks fitted to prevent unsafe operation or unauthorized use are to be checked for normal function.
(11) The electrical equipment and cables installed in areas possibly containing flammable gas and vapour and/or flammable dust are to be examined as follows:

① the integrity of explosion-proof electrical equipment will not be damaged due to corrosion, fallen bolts, etc.;
② no excessive dust accumulation exists in or on dust explosion proof equipment;
③ cables are to be examined so far as possible to confirm that they are perfectly sheathed and armoured and that their fasteners are in good condition;
④ bonding straps for the control of static electricity are to be tested to confirm their effectiveness;
⑤ alarms and interlocks corresponding to spaces under pressurized protection and their pressurizing equipment are to be tested to confirm their proper working condition.

Section 5 INITIAL CLASSIFICATION SURVEY

1.5.1 Initial classification of existing ships

1.5.1.1 General requirements
(1) For the purpose of this Section, existing ships include the following ships in service:

① ships which have been surveyed by classification societies and other survey organizations accepted by ISC;
② ships which have been surveyed by other classification societies not accepted by ISC;
③ ships which have been surveyed by ISC.

(2) The classification stated in this paragraph covers also class notations.
1.5.1.2 Initial classification of ships which have been surveyed by classification societies and other survey organizations accepted by ISC
(1) Initial classification of ships under construction

① Submission of plans
ISC requirements for surveys of ships under construction are to be complied with, i.e. all plans, calculations and other technical documents for construction (approved by other survey organizations according to their rules) are to be submitted to ISC for check. The construction of these ships may, in general, continue in accordance with the approved plans.
② In addition to the normal items for newbuildings, the following items are to be checked (unless they have been checked and relevant records made by classification societies accepted by ISC):
a. the shipyard is to submit records of the checked or confirmed items for review;
b. the Surveyor is to carry out an overall survey of the compartments, spaces and installations which have been inspected and confirm that materials, scantlings, workmanship and arrangements are in compliance with the approved plans;
c. the information on the attended inspections and tests of compartments is to be accepted when such information is confirmed as authentic. When some of the compartments are to be tested again, e.g. functional tests during sea trial and in particular the inspection and testing of cargo holds and ballast tanks, the new tests are to be attended;
d. the records of NDTs are to be checked and sampled. Any NDT is to comply with the rule provisions;
e. the materials (including forgings and castings) used for construction, and manufacturing and

testing of anchors and anchor chains are to meet the requirements of the accepted standards;

f. main propulsion machinery and essential auxiliaries are to be manufactured, installed and tested in accordance with ISC rules or the standards acceptable to ISC;

g. the anchors and anchor chains are to be inspected and certified in accordance with ISC rules, if they have not been delivered to the shipyard;

h. all outstanding recommendations are to be completed.

(2) Initial classification of ships of which the construction has been completed but which have not been put into service

① Submission of plans

a. The owner applying for an initial survey of a ship which has been certified by another survey organization, is to submit at least one copy each of the plans, calculations and other technical documents to ISC for check:

(a) general arrangement;
(b) capacity plan;
(c) hydrostatic curves;
(d) loading manual (if required);
(e) transverse midship section;
(f) construction profile, including longitudinal section, decks, inner bottom structure, superstructure and upper deck structure;
(g) transverse bulkhead;
(h) shell expansion;
(i) rudder and rudder stock;
(j) hatch covers;
(k) engine room arrangement;
(l) intermediate shaft, thrust shaft and propeller shaft;
(m) propeller;
(n) main engine, propulsion machinery and clutch systems (or manufacturer, model and specifications);
(o) in addition, main boiler, superheater and economizer (or manufacturer, model and specifications) and steam piping for steam turbine ships;
(p) bilge and ballast piping diagram;
(q) electrical system;
(r) steering gear piping system and arrangement, manufacturer and model;
(s) torsional vibration calculations;
(t) elastic coupling of propulsion shafting and/or shaft torque limiter (or manufacturer, model and specifications) additionally required for ships with ice class notation;
(u) additional plans required for oil tankers:
i) pumping arrangement at the forward and after ends and drainage of cofferdams and pump rooms;
(v) additional plans required for periodically unattended machinery spaces:
i) measuring instruments and checklist of alarms;
ii) arrangement of fixed fire detection and alarm system;
iii) diagram of automatic safety function tests;
(w) any other information requested by the Flag State Administration;
(x) calculations of damage stability, if required;
(y) approval documents of alternative design and arrangement, if any.

b. For ships which have not been certified by other survey organizations, plans and information are to be submitted in accordance with 1.5.1.2(2)①a.

② Scope of surveys

a. The scope of surveys and examinations of ships which have been certified by other survey organizations are to cover at least the following (unless they have been checked and relevant records made by other survey organizations):

(a) main engines and essential auxiliary machineries, including steering gear, are to be examined under working conditions, and essential automatic controls and alarms are to be subject to functional test;
(b) main boilers, auxiliary boilers for essential services, economizers and steam generators are to be internally examined, safety valves and main attachments opened up and examined;
(c) if the propeller shaft is fitted with oil seal, the aft end and bearings of the shaft are to be

examined;

(d) pumping systems, in particular bilge pumps, are to be tested;

(e) insulation resistance of electrical installations is to be tested;

(f) when the duration exceeds 12 months from the date of the ship's launching, a docking survey is to be carried out;

(g) essential equipment is to be subject to function test and the machinery opened for examination when the Surveyor considers it necessary;

(h) compliance of all pressure vessels with the drawings and certificates provided is to be confirmed.

b. The scope of surveys and examinations of ships which have not been certified by classification societies accepted by ISC are to cover at least the following:

(a) the scope of surveys and examinations is to be in accordance with 1.5.1.2(2)②a;

(b) the owner is to submit records and reports related to surveys, testing and measurement during original construction as well as certificates, test information, etc. for main marine products;

(c) the Surveyors are to examine main structural dimensions to confirm compliance with relevant provisions of the Regulations;

(d) if necessary, test and/or survey for confirmation are to be carried out.

(3) Initial classification of ships which have been put into service

① Submission of plans

a. When applying for an initial survey, the owner is to submit at least one copy each of the plans, calculations and other technical documents specified in 1.5.1.2(2) ① a to ISC for check. However, the submission of torsional vibration calculations may be exempted for ships over 2 years of age.

b. Where the plans and documents can not be submitted according to (a) above, ISC may accept other relevant information as equivalent.

c. Where the information on stability including intact, subdivision and damage stability and the loading manual have been approved by the Flag State Administration or an organization authorized by it and compliance of the arrangement on board the ship with the approved information has been confirmed by ISC, ISC may accept the approved information as the basis for assigning class or issuing certificates.

② Scope of surveys

a. In addition to the items corresponding to ship's age and losing class/survey organizations status, the scope of surveys is to cover the following:

(a) Hull:

a) for ships of less than 5 years of age, an annual survey is to be carried out;

b) for ships 5 years and over but less than 10 years of age, an annual survey and an inspection of an appropriate number of representative ballast tanks, including fore peak tank, after peak tank, top side tank, bottom side tank and double bottom tank, are to be carried out;

c) for ships of 10 years and over but less than 20 years of age, an annual survey and an inspection of an appropriate number of representative ballast tanks and cargo spaces are to be carried out;

d) for ships of 15 years and over but less than 20 years of age, the requirements for special or intermediate surveys (whichever is due) are to be complied with;

e) for ships of 20 years and over, the requirements for special surveys are to be complied with;

f) the latest dry-dock survey report of the losing classification society/survey organization may be accepted if found in compliance with ISC rules upon review.

(b) Machinery (including electrical installations):

a) for ships of less than 10 years of age, an annual survey is to be carried out;

b) for ships of 10 and over but less than 15 years of age, in addition to the requirement under a) above, representative cylinders of main and auxiliary engines are to be lifted and examined;

c) for ships of 15 and over but less than 20 years of age, the requirements for special or intermediate surveys (whichever is due) are to be complied with;

d) for ships of 20 years and over, the requirements for special surveys are to be complied with.

(c) Any conditions of class or recommendations and overdue items previously issued by the losing society/survey organization are to be completed, unless not required by the Regulations.

③ After the plan check and surveys stated in 1.5.1.2(3)① and ②, the interval between surveys may be corresponding to that of the losing society/survey organization.

1.5.1.3 Initial classification of ships which have been surveyed by classification societies not accepted by ISC

(1) Ships under construction

① Submission of plans

ISC requirements for surveys of ships under construction are to be complied with, i.e. all plans, calculations and other technical documents for construction are to be submitted to ISC for approval. Where any change is made in the originally approved plans as the result of the examination, the construction is to be rectified in accordance with the re-approved plans.

② Surveys

a. In addition to the normal items for newbuildings, the following items are to be checked:

a) the shipyard is to submit records of the checked or confirmed items for review; ISC will sample a certain portion of such items, depending on their respective importance levels;

b) the Surveyor is to carry out an overall survey of the compartments, spaces and installations which have been inspected and confirm that materials, scantlings, workmanship and arrangements are in compliance with the approved plans;

c) the information on the attended inspections and tests of compartments is to be accepted when such information is confirmed as authentic. When some of the compartments are to be tested again, e.g. functional tests during sea trial and in particular the inspection and testing of cargo holds and ballast tanks, the new tests are to be attended;

d) the records of NDTs are to be checked and sampled. Any NDT is to comply with the rule provisions;

e) the materials (including forgings and castings) used for construction, and manufacturing and testing of anchors and anchor chains are to meet the requirements of the accepted standards;

f) main propulsion machinery and essential auxiliaries are to be manufactured, installed and tested in accordance with ISC rules or the standards acceptable to ISC;

g) the anchors and anchor chains are to be inspected and certified in accordance with ISC rules, if they have not been delivered to the shipyard;

h) all outstanding recommendations are to be completed.

(2) Initial classification of ships of which the construction has been completed but which have not been put into service

① Submission of plans

When applying for an initial survey, the owner is to submit one copy each of the plans, calculations and other technical documents specified in 1.5.1.2(2)①a to ISC for approval. In general, such ships are to comply with the present rules of ISC, at least with ISC rules effective during construction of the ships.

② Scope of surveys

Survey items are to be in accordance with 1.5.1.2(2)②.

(3) Initial classification of ships which have been put into service

① Submission of plans

When applying for an initial survey, the owner is to submit one copy each of the plans and documents specified in 1.5.1.2(2) ① a to ISC for check. Where ISC is authorized to issue statutory certificates, the stability information including intact, subdivision and damage stability and the loading manual are to be examined and approved by ISC.

② Scope of surveys

The scope of surveys in accordance with the requirements of the Regulations for ships of the same type and age, is to include special survey, dry-dock survey and surveys of screwshaft, stern tube shaft and boilers.

1.5.1.4 Initial classification of ships which have been surveyed by ISC

(1) Ships are to be inspected for compliance with the requested characters of classification and class notations and upon confirmation of such compliance, classification certificates may be issued.

(2) Where a new class notation or a change of the service category is intended for the ship, relevant drawings and documents are to be provided by the owner for approval. When the ship is inspected and

found to be in compliance with relevant requirements, the classification certificate may be issued.
(3) Where any outstanding item affecting classification exists, an occasional survey is to be carried out and upon confirmation of completion of such item, the classification certificate may be issued.

Appendix 1 CORROSION AND WASTAGE CONTROL OF HULL STRUCTURE

1 Criteria for longitudinal strength

1.1 For ships of 65 m and over in length, the hull girder section modulus at deck and bottom within 0.4L amidships is not to be less than 0.9 times the hull girder section modulus required for ships of each service category in Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages, unless provided otherwise.

1.2 For bulk carriers, passenger ships, container ships of 65 m and over in length and of 20 year of age or over, oil tanker of 15 years of age or over and dry cargo ships and other ships of 25 years of age or over, the minimum midship section modulus of corroded members is to be calculated according to thickness measurement results and checked according to the above criteria, at special surveys. Where any limit is exceeded, repairs are to be made to strengthen the structure in compliance with the requirements for longitudinal strength. In the case of excessively corroded members, the minimum midship section modulus is to be calculated and the longitudinal strength checked, regardless of the ages specified above.

2 Criteria for local strength

2.1 For ships constructed in accordance with ISC Rules for Construction of Sea-Going Steel Ships Engaged on Domestic Voyages and ISC Rules for the Construction and Classification of Sea-Going Steel Ships of versions 1996 and 2001, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness by the relevant percentage shown in Table 2.1 below.

2.2 For ships constructed in accordance with ISC Rules for the Construction and Classification of Sea-Going Steel Ships published before 1996, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness by the relevant percentage shown in Table 2.2 below.

2.3 For ships constructed in accordance with ISC Rules for the Construction and Classification of Sea-Going Steel Ships published of versions 2006 and later, relevant provisions in PART ONE of the Rules are to be complied with.

Table 2.1

Structural member	Minimum renewal thickness	
	L ⩾ 90 m	L < 90 m
① Strength deck plating, side shell, top strake, bilge strake, bottom shell, flat plate keel, inner bottom, continuous longitudinal bulkhead, hopper tank and topside tank plating. ② Main longitudinal continuous members, e.g. deck girders, hatch side girders, side girders, bottom girders, bulkhead girders, continuous hatch coamings. ③ Main transverse members, e.g. side frame webs, deck transverses, double plate floors, bulkhead webs, watertight and oiltight transverse bracket plates. ④ Transverse bulkhead plating in holds, upper and lower bulkhead stool sloping plating, watertight bulkhead plating in deep tanks	80%	75%
Other plating and structural members, e.g. deck within line of openings, deck longitudinals, side longitudinals, bottom longitudinals, inner bottom longitudinals, bulkhead longitudinals, face plates of side frames, brackets of structural members, hatch covers, non-continuous hatch coamings, sea chests	75%	70%
Note: For bulk carriers designed in accordance with the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages and assigned the class notations of "Strengthened for Heavy Cargoes", the minimum renewal thickness of inner bottom may be taken as the value obtained by multiplying the as-built thickness and 75%		

Table 2.2

Structural member	Minimum renewal thickness		
	Service category beyond service category 1	Service category 1	Service categories 2 and 3
Strength deck plating, side and bottom shell;	75%	70%	65%
Continuous longitudinal strength members and web frames;	75%	70%	65%
Foundations of main engines, cranes and windlasses	75%	75%	75%
Other structural members defined in the Rules for the Construction and Classification of Sea-Going Steel Ships	70%	60%	55%

2.3 The thickness reduction of hull plating and structural members caused by corrosion and wastage is not to be more than required by ISC rules.

2.4 For bulk carriers contracted for construction on or after 1 July 2017 and complying with Section 8, Chapter 8, PART TWO of ISC Rules for Construction of Sea-Going Steel Ships Engaged on Domestic Voyages, corrosion allowance and renewal requirements for the hatch covers and coamings are as follows:

2.4.1 Hatch cover:

For single skin hatch covers, the corrosion allowance t_s for all structures (plate and frame) is 2.0mm;

For double skin hatch covers, the corrosion allowance t_s for top or bottom plating is 2.0mm and the corrosion allowance t_s for internal structure is 1.5mm.

For plating of double skin hatch covers and single skin hatch covers, renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is t_{net} +0.5mm and over but less than t_{net} +1.0mm, coating or annual gauging may be adopted as an alternative to renewal. The coating is to be maintained in "GOOD" condition, which refers to condition with only minor spot rusting.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of ISC Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, renewal for the internal structures is required where the gauged thickness is less than t_{net}.

2.4.2 Hatch coaming

Corrosion allowance t_s for hatch coaming structure and coaming stay is 1.5mm.

Renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is t_{net} +0.5 mm and over but less than t_{net} +1.0 mm, coating or annual gauging may be adopted as an alternative to renewal. The coating is to be maintained in "GOOD" condition.

2.5 For ships other than bulk carriers, ore carriers and combination carriers, contracted for construction on or after 1 July 2017 and complying with Section 20, Chapter 2, PART TWO of the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages, and for all weathertight steel cargo hatch covers on exposed decks, steel renewal is required where the gauged thickness of the plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (the coating is to be maintained in "GOOD" condition, meaning condition with only minor spot rusting) or annual gauging may be adopted as an alternative to steel renewal. For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of ISC Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. For corrosion addition t_s = 1.0 mm, the thickness for steel renewal is t_{net}, and when gauged thickness is between t_{net} and t_{net} + 0.5 mm, coating or annual gauging may be adopted as an alternative to steel renewal, where t_{net} being the net thickness, to be calculated in accordance with 2.20.2, Section 20, Chapter 2, PART TWO of the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages.

Appendix 2 MINIMUM INSULATION RESISTANCE OF ELECTRICAL EQUIPMENT AND CIRCUITS IN HOT CONDITION

The test results of insulation resistance of electrical equipment and circuits, as required by 1.4.3.1(2)② and 1.4.4.2(2) are in general not to be less than the following values.

Item	Insulation resistance in hot condition(MΩ)	
	Working voltage ≤ 100 V	Working voltage > 100 V
Motor	—	0.5
Propulsion motor	—	3U/(1000 + P)
Exciters, excitation winding and control gear for electrical propulsion	—	1.0
Various switchboards	—	0.5
Final sub-circuit of lighting distribution boards (except for fan and small electrical appliance)	0.2	0.5
Transformers	—	1.0
Control gear	0.2	0.5
Internal communication and alarm systems	0.3	0.5
Heating appliances	—	0.5
Circuits of navigation lights	—	1.0

Notes:

① *U* is the rated working voltage (V) and *P* the rated capacity in kW or kVA.

② For working voltage of 100 V or over, the insulation resistance is to be measured with a D.C. 500 V megger at least. For working voltage less than 100 V, the insulation resistance is to be measured with a D.C. 250 V megger.

③ The insulation resistance of electrical equipment may be measured only between polarity (phase) and earth.

④ The resistance of turbo-generator rotors is to be measured at the rated speed.

Appendix 3 MARKING OF LOAD LINES

1 Application

1.1 The requirements of this Appendix apply to classed ships engaged on non-international voyages.

2 Load line marks

2.1 The load line mark for ships not carrying timber deck cargoes is shown in Figure 2.1.

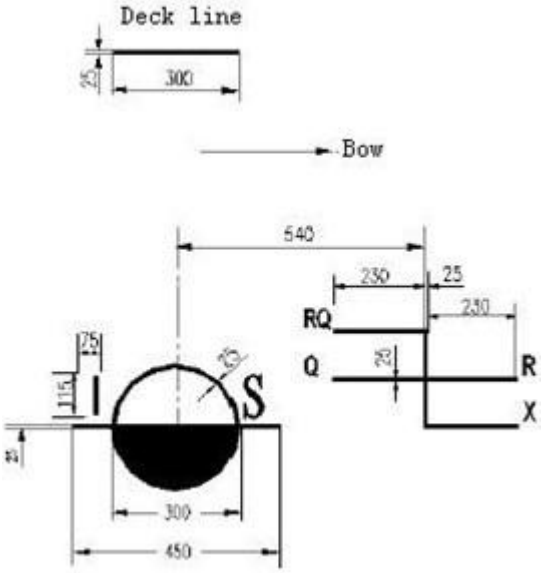


Figure 2.1 Freeboard Mark for Ships not Carrying Timber Deck Cargoes (in mm)

2.2 The load line mark for ships carrying timber deck cargoes is shown in Figure 2.2.

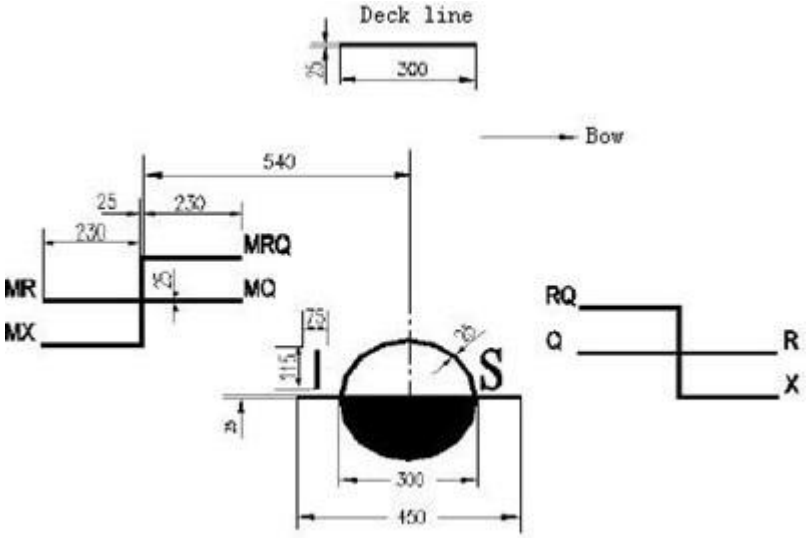


Figure 2.2 Freeboard Mark for Ships Carrying Timber Deck Cargoes (in mm)

2.3 Where a ship is assigned a greater than minimum freeboard so that the load line is marked at a position corresponding to, or lower than, the lowest seasonal load line assigned at minimum freeboard as specified in the LL Convention, only the Fresh Water Load Line need be marked. In such a case, the load line mark is as shown in Figure 2.3 and may also be marked in accordance with Figure 2.1.

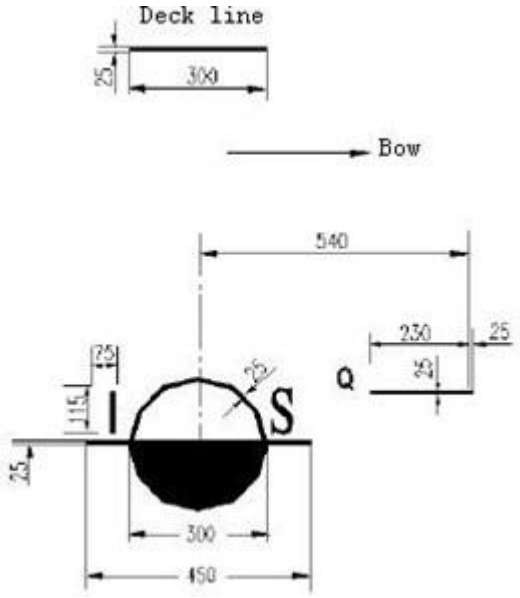
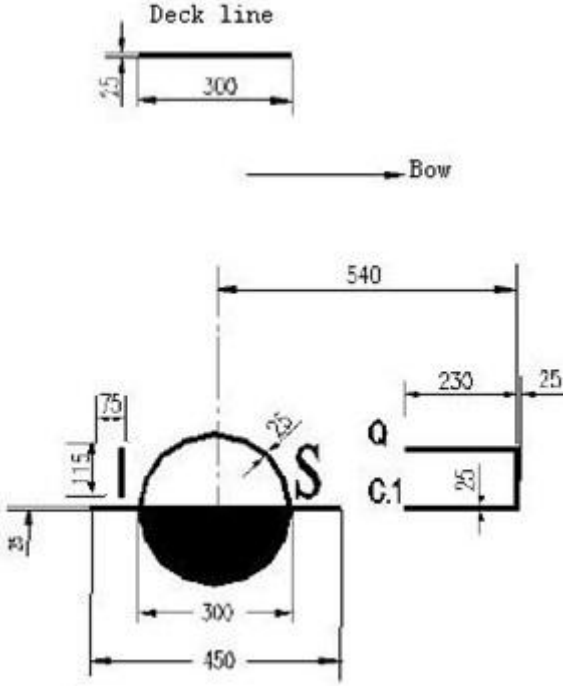


Figure 2.3 Fresh Water Load Line Only (in mm)



2.4 The subdivision load line mark for passenger ships is shown in Figure 2.4.

Figure 2.4 Subdivision Load Line Mark for Passenger Ships (in mm)

The symbols in Figures 2.1 to 2.4 are defined as follows:
IS — International Ship Classification;
RQ — Tropical Fresh Water Load Line;
Q — Summer Fresh Water Load Line;
R — Tropical Load Line;
X — Summer Load Line;
MRQ — Tropical Fresh Water Timber Load Line;
MQ — Summer Fresh Water Timber Load Line;
MR — Tropical Timber Load Line;
MX — Summer Timber Load Line;

C.1 — Passenger Ship Subdivision Load Line.

3 Marking

3.1 The Load line mark is to consist of a ring 300 mm in outside diameter and 25 mm wide which is intersected by a horizontal line 450 mm in length and 25 mm in breadth; the upper edge of horizontal line passes through the center of the ring. The center of the ring is to be placed on each side of the ship at the middle of the length as defined in LL Convention, and the vertical distance from the upper edge of the deck line to the center of the ring is equal to the assigned summer freeboard. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are to be permanently marked on both sides of the ship and clearly visible.

CHAPTER 2 HULL

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 The definition of restricted service is given in Section 1, Chapter 0 of this PART.

2.1.1.2 The environmental conditions corresponding to restricted services are given in Table 2.1.1.2.

Table 2.1.1.2

Restricted service	Significant wave height
Service category 1	0.78*C*
Service category 2	0.74*C*
Service category 3	0.69*C*

C —coefficient to be obtained from the following formulae:

$C = 0.0412L + 4$ for $L<90$ m;

$C = 10.75 - \left(\frac{300 - L}{100}\right)^{3/2}$ for $90 \le L \le 300$ m;

$C = 10.75$ for $300 < L < 350$ m;

$C = 10.75 - \left(\frac{L - 350}{150}\right)^{3/2}$ for $350 \le L \le 500$ m.

L— length of ship, in m, see 1.1.2.1, Section 1, Chapter 1, PART TWO of the Rules.

2.1.2 Longitudinal strength

2.1.2.1 The values of the minimum midship section modulus W_0 for the calculation of longitudinal strength in accordance with the requirements of Section 2, Chapter 2, PART TWO of the Rules may be reduced by:

(1) 5% for ships intended for service category 1;

(2) 10% for ships intended for service category 2;

(3) 15% for ships intended for service category 3.

2.1.2.2 For the check of longitudinal strength of ships in accordance with the requirements of Section 2, Chapter 2 or Sections 2 and 10, Chapter 7 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced by:

(1) 10% for ships intended for service category 1;

(2) 15% for ships intended for service category 2;

(3) 20% for ships intended for service category 3.

2.1.2.3 For engineering ships assigned with different notations for transiting and operation, the wave bending moment and wave shear force reduction requirements of the corresponding area are to be used in different conditions to check longitudinal strength of ships.

2.1.3 Reduction of rule scantlings of structural members

2.1.3.1 For ships intended for navigating in restricted service, the scantlings of structural members, as calculated in accordance with the requirements of PART TWO of the Rules other than those of 2.1.3.2 and 2.1.3.3 of this Section, refer only to the Rule plate thickness, sectional area and section modulus of structural members, and may be reduced by:

(1) 5% for ships intended for service category 1;

(2) 10% for ships intended for service category 2;

(3) 15% for ships intended for service category 3.

The scantlings of structures after reduction are to comply with the requirements of 2.1.3.4 of this Section.

2.1.3.2 For ships equal to or greater than 65 m in length, where the values of the reduction factors F_d and/or F_b required in Section 2 of Chapter 2 of PART TWO are less than 1, the following requirements are to be complied with when calculating the thickness of shell plating and main deck within 0.4*L* amidships:

(1) where the value of F_d is less than 1, the thickness of main deck and sheer strake is not to be reduced in accordance with the requirements of 2.1.3.1 of this Section;

(2) where the value of F_b is less than 1, the thickness of bottom plating and bilge strake is not to be reduced in accordance with the requirements of 2.1.3.1 of this Section;

(3) where the value of F_d or F_b is less than 1, the thickness of side shell plating is not to be reduced in accordance with the requirements of 2.1.3.1 of this Section.

2.1.3.3 The rule scantlings in the following conditions are not to be reduced in accordance with the requirements in 2.1.3.1: the rule minimum thickness, scantlings of structural members for which ice strengthening and strengthening of bottom forward are required, and bulkhead, structural members of deep tanks and cargo tanks, inner bottom plating and framing for loading heavy cargoes, cargo deck framing, vehicle decks, pillars, stems, stern frames, propeller shaft brackets, main engine seating structures, rudders, etc.

2.1.3.4 The requirements for thickness of plating after reduction

(1) For ships of less than 65 m in length, the thickness of shell plating is to be not less than 5 mm.

(2) For ships of less than 65 m in length, the thickness of strength deck is to be not less than 5 mm and the thickness of other decks is to be not less than 4 mm.

(3) For ships of less than 65 m in length, the thickness of inner bottom plating in double bottom is to be not less than 5 mm.

(4) For ships of less than 65 m in length, the thickness of weather tight steel hatch covers is to be not less than 5 mm.

2.1.3.5 For ships of less than 40 m in length, the spacing *s* of frames may be taken as the full-scale spacing of frames when calculating the thickness of transversely framed bottom plating.

2.1.3.6 The thickness of the plate keels is not to be less than the calculated value of rule required thickness of the bottom plating plus 1.5 mm, and in no case less than that of the adjacent bottom plating.

2.1.3.7 Ships intended for service category 2 or 3 need not meet the requirements of fore deck fittings in Section 7, Chapter 1, PART TWO of the Rules.

2.1.3.8 Ships intended for service category 2 or 3 need not meet the requirements for strengthening of bottom forward in Section 15, Chapter 2, PART TWO of the Rules.

2.1.3.9 Ships engaged on non-international voyages need not meet the requirements for strengthening of grabs in Section 23, Chapter 2, PART TWO of the Rules depending on a voluntary basis by the shipowner.

2.1.3.10 Bulk carriers engaged on non-international voyages need not meet the requirements of Sections 8, 9, 10, 12, 13 and 15, Chapter 8, PART TWO of the Rules.

2.1.4 Anchoring equipment

2.1.4.1 The number of pieces of the anchoring equipment required in Section 2, Chapter 3, PART TWO of the Rules may be reduced in accordance with the following requirements:

(1) Except as required in (2) of this paragraph, the anchoring equipment of ships intended for service category 2 may be selected one grade lower than required by the equipment number *N*. For traffic boats or ferry boats less than 30 m in length, one single bower anchor and one half of the required length of chain cable will be acceptable.

(2) For floating cranes, floating pile drivers or other similar working ships and trailing suction dredgers intended for service category 2, the anchoring equipment may be selected two grades lower than required by the equipment number *N*.

(3) For ships intended for service category 3, the anchoring equipment may be selected two grades lower than required by the equipment number *N*. For traffic boats or ferry boats of less than 30 m in length, one single bower anchor and one half of the required length of chain cable will be acceptable.

(4) For ships intended for operations in harbours with breakwater, the anchoring equipment may be selected a half grade lower than required by the equipment number *N* and one half of the required length of chain cable will be acceptable.

2.1.4.2 The ultra high holding power anchors may be used as bower anchors for ships navigating in restricted service. The mass of each ultra high holding power anchor may be 50% of that of an ordinary stockless bower anchor as specified in Table 3.2.1.1(2), Chapter 3, PART TWO of the Rules. The mass of each ultra high holding power anchor is generally not to exceed 1,500 kg, for details see Section 1, Chapter 10 of PART ONE of ISC Rules for Materials and Welding.

2.1.5 Stability, load line and structural arrangement

2.1.5.1 The stability, load line and structural arrangement of ships engaged on non-international voyages are to comply with the relevant provisions of the flag State Administration.

2.1.6 Loading manual and loading instrument

2.1.6.1 Ships of service category 2 and service category 3 may not be provided with a loading instrument.

2.1.6.2 For ships engaged on non-international voyages, the loading manual, output results of loading instrument and operation manual are to use the language that users can understand. Where this language is not English, English translation may not be required.

2.1.7 Direct calculations

2.1.7.1 When the requirements of Section 5 Direct strength calculations, Chapter 1, PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.1.7.2 are to be satisfied.

2.1.7.2 The service coefficient f_r , is to be taken as follows:

f_r=0.90, for service category 1;

f_r=0.85, for service category 2;

f_r=0.80, for service category 3.

2.1.7.3 When the requirements of 2.2.9 Direct calculation of wave loads, Section 2, Chapter 2, PART TWO of the Rules are applicable to ships in restricted service,the prediction of wave loads is required to be based on wave statistics of the sea areas in which such ships operate and where there are more than one set of wave statistics, the most severe one is to be used.

Section 2 SHIP TYPE REQUIREMENTS

2.2.1 Ro-ro ships, passenger ships, ro-ro passenger ships and ferries

2.2.1.1 When the requirements of Section 4 Bow doors and inner doors, Section 5 Side shell and stern doors of Chapter 9 of PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.2.1.2 are to be satisfied.

2.2.1.2 The design load coefficient λ is to be determined in accordance with the following requirements:

λ=1.0, for ships intended for service category 1;

λ=0.8, for ships intended for service category 2;

λ=0.5, for ships intended for service category 3.

2.2.1.3 For passenger ships intended for service category 2 or 3, and of less than 65 m in length, the superstructure and deckhouse of tier 2 and above and not participating in hull girder longitudinal bending may use aluminium alloy reinforced plate. For passenger ships of 65 m and more in length, special consideration may be given to the superstructure and deckhouse not participating in hull girder longitudinal bending.

2.2.1.4 Where aluminium alloy reinforced plate is used in the superstructures and deckhouses mentioned in 2.2.1.3 above, the thickness of the plate may be determined in accordance with the principle of strength equivalence as specified in Section 17, Chapter 2 and Section 2, Chapter 9, PART TWO of the Rules, but not less than 5 mm.

2.2.2 Barges

2.2.2.1 When the requirements of Appendix Method of checking transverse strength of pontoon barges of Chapter 12 of PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.2.2.2 are to be satisfied.

2.2.2.2 For pontoon barges navigating only in restricted service, the value C used for the load due to external water pressuremay be reduced in accordance with the following provisions:

(1) for service category 1: 0.90;

(2) for service category 2: 0.85;

(3) for service category 3: 0.80.

2.2.3 Floating cranes

2.2.3.1 For floating cranes operating in restricted service, the following class notations are to be assigned:

(1) Operating in Service category 1: Lifting Within R1;

(2) Operating in Service category 2: Lifting Within R2;

(3) Operating in Service category 3: Lifting Within R3;

(4) Operating only within harbour: Lifting Within Harbour.

2.2.3.2 For the check of longitudinal strength of floating cranes under operating conditions in accordance with the requirements of Chapter 13 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced as follows:

(1) 15% for ships intended for service category 1;

(2) 30% for ships intended for service category 2;
(3) 45% for ships intended for service category 3;
(4) 70% for floating cranes intended for operations in harbours only.

2.2.4 Dredgers

2.2.4.1 Dredgers operating in restricted service are to be assigned one of the following class notations:
(1) Operating in service category 3: Dredging Within R3;
(2) Operating in service category 2: Dredging Within R2;
(3) Operating in service category 1: Dredging Within R1;
(4) Operating only within harbour: Dredging Within Harbour.
2.2.4.2 For the check of longitudinal strength of dredgers under operating conditions in accordance with the requirements of Chapter 14 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced as follows:
(1) 15% for ships intended for service category 1;
(2) 30% for ships intended for service category 2;
(3) 45% for ships intended for service category 3;
(4) 70% for dredgers intended for operations in harbours only.

2.2.5 Semi-submersible barges

2.2.5.1 For non-self-propelled semi-submersible barges designed for operation in service category 3 or in harbour, loads and calculation conditions of longitudinal strength under the operating condition may be calculated in accordance with relevant requirements of ISC Rules for Classification of Floating Docks.

2.2.6 Twin-hull craft

2.2.6.1 Where Section 3 Total load, Chapter 18, PART TWO of the Rules is applicable to ships in restricted service, the requirements of 2.2.6.2 are to be satisfied.
2.2.6.2 For twin-hull craft only intended for the restricted service, the service coefficient C_3 of calculation of loads may be reduced as follows:
(1) 0.8 for service category 1;
(2) 0.6 for service category 2;
(3) 0.5 for service category 3.
.

CHAPTER 3 MACHINERY INSTALLATIONS

Section 1 GENERAL PROVISIONS

3.1.1 Scope of application

3.1.1.1 The provisions of this Chapter apply to machinery installations of ships in restricted service, which can replace relevant provisions in PART THREE of the Rules.

3.1.2 Ambient conditions

3.1.2.1 For machinery installations of ships in restricted service related to ship classification, the ambient temperature required in Table 1.2.1.2 of PART THREE of the Rules may be selected in accordance with the practical condition of service area.

3.1.2.2 In the case of ships for restricted service, the ambient conditions used for determining the rating of main and auxiliary diesel engines as required by 1.2.1.3 of PART THREE of the Rules are to be suitable for the geographical limits of the restricted service.

3.1.3 Fuel

3.1.3.1 With regard to the flash point required by 1.2.9.1 of PART THREE of the Rules, in ships engaged on non-international voyages, where additional precautions are taken so that the ambient temperature of the space in which oil fuel is stored or used will not be allowed to rise to within 10℃ below the flashpoint of the oil fuel, the use of oil fuel having a flashpoint of less than 60 ℃ but not less than 43 ℃ may be permitted.

Section 2 MACHINERY INSTALLATIONS

3.2.1 Dead ship starting

3.2.1.1 For cargo ships with service category 2 and lower than category 2 and passenger ships with service category 3 engaged on non-international voyages, dead ship starting in 1.2.6 of PART THREE of the Rules is not required.

3.2.2 Bilge suction arrangement in machinery spaces

3.2.2.1 For cargo ships with service category 2 and lower than category 2, the number of direct bilge suctions in Table 3.3.2.1 of PART THREE of the Rules may be 1.

3.2.2.2 For passenger ships engaged on non-international voyages of less than 100 gross tonnage or passenger ships with service category 3 and of less than 500 gross tonnage engaged on non-international voyages, emergency bilge suction as required in 3.3.3.1 of PART THREE of the Rules may be dispensed with.

3.2.3 Bilge pumps and bilge piping

3.2.3.1 With regard to the number of power bilge pumps and drive modes for each ship as specified in Table 3.4.1.1 of PART THREE of the Rules, for ships engaged on non-international voyages of less than 100 gross tonnage, carrying not more than 100 passengers, 2 independent bilge pumps may be provided if navigation period is less than 4 h.

3.2.4 Oil tank air pipes

3.2.4.1 Paragraph 3.10.2.5 of Chapter 3 of PART THREE of the Rules does not apply to ships with service category 2 and lower than category 2 engaged on non-international voyages,

3.2.5 Oil tank short sounding pipes

3.2.5.1 For ships engaged on non-international voyages, if high-level alarms are fitted in fuel oil tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) of Chapter 3 of PART THREE of the Rules are to be met.

3.2.5.2 For fuel oil tanks in double bottom tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) of Chapter 3 of PART THREE of the Rules are to be met for ships with service category 2 and lower than category 2 engaged on non-international voyages.

3.2.6 Fuel oil daily tank

3.2.6.1 For ships intended for navigating in restricted service engaged on non-international voyages, the capacity of each fuel oil daily tank required in 4.2.1.8 of Chapter 4 of PART THREE of the Rules may be reduced depending on different conditions but not less than 4 h.

3.2.6.2 The requirements of 4.2.1.8 of Chapter 4 of PART THREE of the Rules may not apply to ships with service category 3.

3.2.7 Oil burning units of boilers

3.2.7.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil as specified in 4.2.2.2 of PART THREE of the Rules, one oil supply unit will be accepted provided that one complete spare oil burning pump is carried on board and capable of being easily installed and connected.

3.2.8 Oil fuel booster pumps

3.2.8.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for oil fuel booster pumps as required in 4.2.3.1 of PART THREE of the Rules, where one complete spare pump capable of being easily installed and connected or a suitable pump connecting to the system is provided, a standby pump may be dispensed with.

3.2.9 Feed water pumps for boilers

3.2.9.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil and cargo oil as specified in 4.4.1.1 of PART THREE of the Rules, where one feed water pump capable of being easily installed and connected is provided, only one feed water pump fitted is acceptable.

3.2.10 Feed water systems for boilers

3.2.10.1 For auxiliary boilers fitted with only one feed water pump as required in 3.2.9.1 of this Section, the requirements for provision of two independent feed water systems in 4.4.2.1 of Chapter 4 of PART THREE of the Rules may not be applied.

3.2.11 Condensate pumps

3.2.11.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, if not propelled by steam, the standby pump within condensate pumps required by 4.4.4.1 of PART THREE of the Rules may be one spare pump capable of being easily installed and connected.

3.2.12 Cooling water pumps

3.2.12.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, the standby cooling water pump as required in 4.5.1.1 of PART THREE of the Rules may be substituted by other pump with sufficient discharge capacity or a complete spare pump capable of being easily installed and connected.

3.2.13 Lubricating oil pumps

3.2.13.1 For ships intended for navigating in restricted service, where the power of single main engine is less than 440 kW, the standby pump as required in 4.6.1.1 of Chapter 4 of PART THREE of the Rules may be dispensed with.

3.2.14 Alternative power supply for steering gear

3.2.14.1 The requirements in 13.1.8.6 of Chapter 13 of PART THREE of the Rules may not apply to ships with service category 3 engaged on non-international voyages.

CHAPTER 4 ELECTRICAL INSTALLATIONS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

4.1.1 Generating sets

4.1.1.1 Ships engaged on non-international voyages with the total capacity of the main generating sets of 500 kVA or less need not comply with the provisions in 2.1.1.1(4)② of Chapter 2, PART FOUR of the Rules.

4.1.1.2 At least one generating set is to be provided in cargo ships engaged on non-international voyages in category 3 service.

4.1.1.3 At least one generating set is to be provided in passenger ships engaged on non-international voyages in category 3 service where the auxiliary machineries serving the main engine, steering gear oil pumps, fire pumps and bilge pumps are driven by the main engine.

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

4.2.1 Period of power supply

4.2.1.1 For domestic ships engaged on non-international voyages, the period of power supply of the emergency source of electrical power as required in 2.2.2.1 and 2.2.3.1(2) to 2.2.3.1(5) of Chapter 2 of PART FOUR of the Rules may be reduced to:

(1) category 1 service: 12h for passenger ships and 6h for cargo ships;

(2) category 2 service: 6 h for passenger ships and 3 h for cargo ships;

(3) category 3 service: 3 h for passenger ships and 3 h for cargo ships.

4.2.1.2 For passenger ships engaged regularly in international voyages of short duration and proceeding not more than 20 n miles off shore, ISC, if satisfied that the same level of safety would be attained, may accept a lesser period than the 36 h period required in 2.2.2.1(1) to (4), Chapter 2 of PART FOUR of the Rules, but not less than 12 h.

4.2.1.3 For cargo ships engaged regularly in international voyages of short duration and proceeding not more than 20 n miles off shore, ISC, if satisfied that the same level of safety would be attained, may accept a lesser period than the 18 h period required in 2.2.3.1(2) to (5), Chapter 2 of PART FOUR of the Rules, but not less than 12 h.

4.2.2 Reserve power source

4.2.2.1 For ships engaged on non-international voyages in category 3 service, the emergency source of electrical power as required in Section 2, Chapter 2 of PART FOUR of the Rules may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;

② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of PART FOUR;

③ capable of providing immediately power supply for any equipment as required in 4.2.1.1(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;

② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;

③ internal communication equipment required in emergency;

④ fire detection and fire alarm system (if any);

⑤ daylight signalling lamp, the ship's whistle, the manually operated call points (if any) in intermittent

operation and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);

⑥ radio communications on board.

Section 3 MISCELLANEOUS

4.3.1 Transformer

4.3.1.1 Requirements of 2.1.3.1(1) and (2), Chapter 2 of PART FOUR of the Rules may not be met for domestic cargo ships engaged on non-international voyages in category 3 service.

.

CHAPTER 5 REFRIGERATED CARGO INSTALLATIONS

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 Any proposed addition to or relaxation of the requirements of PART FIVE of the Rules in respect to ships navigating in restricted service, to installations of small capacity, or to other special cases is subject to agreement of ISC. In such cases a service limitation may be made to the ship.

5.1.1.2 Cargo chambers are in general not to be refrigerated by the direct expansion pipe grid system when ammonia is used as refrigerant. However, in the case of a ship navigating in restricted service where the total capacity of its refrigerated cargo chambers is less than 500 m^3, a direct expansion ammonia pipe grid system may be adopted.

Section 2 REFRIGERATING PLANT

5.2.1 Number of units

5.2.1.1 In ships classed for restricted service where the total capacity of the refrigerated chambers is less than 1,500 m^3, only one complete refrigerating unit may be provided, but a standby compressor is to be fitted as an addition.

Section 3 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS

5.3.1 Ventilation within holds

5.3.1.1 When Chapter 4 Carriage of refrigerated containers in cargo holds of PART FIVE of the Rules is applicable to ships of restricted service, the ventilation of holds carrying refrigerated containers is to be determined mainly according to size, type, number of containers, type of refrigerated cargo to be carried and service area of the ship.

CHAPTER 6 FIRE PROTECTION, DETECTION AND EXTINCTION

Section 1 GENERAL REQUIREMENTS

6.1.1 Fire protection, detection and extinction of ships engaged on non-international voyages are to satisfy relevant requirements of ISC Guidelines for Statutory Surveys of Sea-Going Ships Engaged on Non-International Voyages or standards accepted by the Administration of the flag State.

CHAPTER 7 ADDITIONAL REQUIREMENTS

Section 1 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS

7.1.1 General requirements

7.1.1.1 This Section applies only to open-top container ships engaged in restricted service.

7.1.1.2 The relevant definitions and the required plans and documents are the same as those given in Section 1, Chapter 6, PART EIGHT of the Rules.

7.1.2 Freeboard

7.1.2.1 The freeboards are to be in compliance with the requirements of the flag Administration. Where not required by the Administration, the minimum freeboard of ships engaged in restricted service may be determined by either:

(1) sea keeping characteristics (model test), intact stability and structural strength; or

(2) minimum geometrical freeboard, intact stability and structural strength.

Where the hull or hatch coaming of open-top container ships is fitted with freeing ports or scuppers, however, the minimum freeboard is to be determined in accordance with (1) of this paragraph.

7.1.2.2 Where the freeboard is determined according to 7.1.2.1(1), the significant wave height for model test and the permissible hourly rate of ingress of green water in any one open hold (hourly rate of shipped green water = open area of hold × hourly down flooding height) are to be in accordance with Table 7.1.2.2:

Table 7.1.2.2

Service	Significant wave height for test① (m)	Hourly down flooding height (mm/h)
Service category 1	7.5	300
Service category 2	5.5	200
Service category 3	3.5	150

Note: ① The significant wave height for model test may be determined according to wave statistics of service areas, subject to agreement of ISC.

The procedure of model tests is to be in accordance with 6.1.6 of Section 1 of Chapter 6 of PART EIGHT of the Rules.

7.1.2.3 Where the freeboard is determined according to 7.1.2.1(2), the minimum freeboard is to be not less than the minimum geometrical freeboards given in Table 7.1.2.3:

Table 7.1.2.3

Service	Minimum geometrical freeboard (m)
Service category 1	0.035 L_L
Service category 2	0.030 L_L
Service category 3	0.0275 L_L

where: L_L– ship's length measured to load line, in m.

7.1.2.4 The minimum bow height is not to be less than that required by the LL 1966, assuming hatch covers being fitted.

7.1.3 Arrangement

7.1.3.1 Where the freeboard is determined according to 7.1.2.1(2),the hull or hatch coaming is not to be fitted with freeing ports or scuppers.

7.1.3.2 A deckhouse, forecastle or breakwater, the width of which is to be not less than that of front coaming of the open-top No.1 hold, is to befitted forward of that hold.

7.1.3.3 The height of the rear top of the deckhouse or forecastle and the top of the breakwater above the summer waterline is to be not less than the values given in Table 7.1.3.3:

Table 7.1.3.3

At forward perpendicular	0.25 L aft of forward perpendicular
F_b + 2.35	F_{min} + 1.75

where: F_b — minimum bow height specified according to 7.1.2.4, in m;

F_{min} — freeboard, in m, determined according to Regulations 27 to 30 of Annex I to the LL 1966, assuming hatch covers being fitted; to be determined by linear interpolation if the top is between the two positions given in the Table.

7.1.3.4 The breakwater structure is to be in compliance with the requirements for hold hatch coamings.

7.1.4 Intact stability

7.1.4.1 The intact stability is to be calculated and checked in accordance with the requirements for general cargo ships in Section 9, Chapter 1 of PART TWO of the Rules.

7.1.4.2 The intact stability in full-load complete flooded condition is to be calculated and checked in accordance with the following requirements.

(1) The full-load complete flooded condition is a full load condition of the ship, assuming open-top holds being flooded to the extent given in Table 7.1.4.2 (in the case of a ship fitted with cargo hold freeing ports, to the level of those ports):

Table 7.1.4.2

Service	Down flooding height of open-top holds (% hold depth*)
Service category 1	85
Service category 2	70
Service category 3	55

* Hold depth is the distance measured from the upper surface of inner bottom of a hold to that of strength deck.

(2) For ships engaged in service of category 1, the intact stability in the complete flooded loading conditions stated in (1) above is to comply with the following criteria:

① the range of stability is to be not less than 20°, and the angles of immersion of openings including ventilators, doors and hatch covers, which cannot be closed weather tight, are to be greater than this value;

② the maximum positive righting lever within the range specified in ① above but not greater than 20° is not to be less than 0.1 m.

(3) For ships engaged in service of category 2 or 3 or equivalent to 3, the intact stability in the complete flooded loading conditions stated in (1) above is to comply with the following criteria:

① the range of stability is to be not less than 15°, and the angles of immersion of openings including hatch coaming top, ventilators, doors and hatch covers, which cannot be closed weather tight, are to be greater than this value;

② the area A_{min} under the righting lever GZ curve within the range of stability which complies with ① above is not to be less than the value obtained as follows:

$$A_{min} = 0.025 + 0.005\,(20° - \theta_f) \quad \text{m·rad}$$

where: θ_f — angle of heel at which openings in hull, superstructures or deckhouses which cannot be closed weather tight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

7.1.5 Damage stability

7.1.5.1 The damage stability is to be in accordance with 6.1.9 of Section 1 of Chapter 6 of PART EIGHT of the Rules or the relevant requirements specified by the flag Administration for conventional container ships.

7.1.6 Strength and construction

7.1.6.1 The longitudinal strength and local strength of the hull are to be checked in accordance with Chapters 2 and 7 of PART TWO of the Rules.

7.1.6.2 In addition, the loading conditions for the check of the longitudinal strength and local strength are to include the full-load complete flooded condition indicated in 7.1.4.2, wherein the assumed down flooding height is to be determined according to Table 7.1.4.2. In loading conditions indicated in 7.1.4.2, the following requirements are to be satisfied:

(1) Where the still water bending moment in flooded condition exceeds the allowable value, or the draught in flooded condition is greater than the scantling draught, the actual still water bending moment and/or draught in flooded condition is to prevail. Hull girder longitudinal strength (including ultimate strength) is to be checked in accordance with Section 2, Chapter 7, PART TWO of the Rules.

(2) Where the draught in flooded condition is greater than the scantling draught, the former is to prevail. Local strength is to be checked in accordance with relevant sections of Chapters 2 and 7, PART TWO of the Rules.

(3) For hull structures forming watertight boundaries of open-top holds, requirements in Section 13 Deep

Tanks, Chapter 2, PART TWO of the Rules are to be satisfied, where the design pressure head h is the vertical distance from the calculation point to the highest point of down flooding height specified in 7.1.4.2.

7.1.6.3 When checking the longitudinal strength, the hatch deformation due to hydrodynamic torque need not be considered.

7.1.7 Bilge dewatering system

7.1.7.1 Where the freeboard is determined according to 7.1.2.1(1), the capacity of the bilge pumping system is to be determined in accordance with the relevant requirements of 6.1.10 of Section 1 of Chapter 6 of PART EIGHT of the Rules.

7.1.7.2 Where the freeboard is determined according to 7.1.2.1(2), the capacity of the bilge pumping system is to be not less than the greatest of the values obtained as follow:

(1) four-thirds of the amount of water required for fire-fighting purposes in the largest hold;

(2) an amount equal to the capacity required for ships with closed cargo holds;

(3) down-flooding height of open-top holds as listed in Table 7.1.7.2 multiplied by open hatch area:

Table 7.1.7.2

Service	Down-flooding height of open-top holds
Service category 1	150 mm/h for No.1 hold, 100 mm/h for other holds
Service category 2	130 mm/h for No.1 hold, 100 mm/h for other holds
Service category 3	100 mm/h for all holds

7.1.7.3 The ship is to be fitted with at least three bilge pumps for pumping open-top hold bilges.

7.1.7.4 The capacity and arrangement of the bilge pumps are to comply with the following requirements:

(1) At least one of these pumps is to have a capacity of not less than the required capacity as defined in 7.1.7.1 or 7.1.7.2 and is to be used for bilge and ballast service. This pump may also be used as an emergency fire pump. The pump is to be located in such a way that it will not be affected by a fire or other casualty to the space containing the pumps required in (2) below or the space containing the main source of power and is to be supplied from the emergency source of power complying with Sections 1 and 2, Chapter 2 of PART FOUR of the Rules or any source of power other than the main source of power. Where the pump is also used as an emergency fire pump, the relevant requirements for emergency fire pumps are to be complied with.

(2) The combined output of at least two further pumps is not to be less than the required capacity as defined in 7.1.7.1 or 7.1.7.2. These pumps are to be supplied from the main source of power complying with Section 1, Chapter 2 of PART FOUR of the Rules, or any source of power other than the emergency source of power.

7.1.7.5 The bilge pumping system is to be arranged to be effective with the ship in upright position and heeled up to 22.5°, or trimmed by bow or stern up to 10°, or with any combination of inclination angles within these scopes. The open hold bilge wells are to be readily accessible for dredging and cleaning.

7.1.7.6 All open cargo holds are to be fitted with high bilge level alarms. The alarms are to initiate visual and audible warnings in the engine room and the manned control locations (navigation bridge or control stations) and be independent of bilge pump controls.

7.1.8 Fire protection

7.1.8.1 Open-top cargo holds are to be protected by a water sprinkler or spray system. The system is to be capable of sprinkling/spraying water into the cargo hold from deck level downward. The system is to be designed and arranged to take account of the specific hold configuration so that the sprinkled/sprayed water will cover the complete hatch of the open hold.

7.1.8.2 At least one dedicated fire-extinguishing pump for the hold water sprinkler or spray system with a capacity to serve all container bays in any one open-top container hold simultaneously is to be provided. The uniform application density is to be not less than 1.1 l/min/m^2. The pump is to be installed outside the open-top area. In addition, the sprinkler or spray system is to be interconnected to an alternative source from the weather deck as backup means, the capacity of which is not to be 50% less than that of the dedicated pump.

7.1.8.3 For open holds of open-top container ships of less than 5,000 gross tonnage, deck fire main system may be an alternative to the sprinkler or spray system required by 7.1.8.1 and 7.1.8.2.

Section 2 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS

7.2.1 General provisions

7.2.1.1 The scope of application of this Section is as follows:

(1) This Section applies only to pusher tug-barge combinations in restricted service.

(2) The pusher tug-barge combinations are to comply with the requirements of this Section and in addition, the applicable requirements in other Chapters of the Rules for single pusher tugs and barges, ISC Rules for Materials and Welding and the relevant requirements of the flag Administration (if any).

7.2.1.2 For the purpose of this Section:

(1) Rigidly connected pusher tug-barge combination is a combination of a pusher tug and a barge with the following characteristics:

The pusher tug is secured in the barge notch by mechanical means of any type whatsoever other than just wire ropes, chains, lines or other tackles, and there is no relative motion between the pusher tug and the barge. The pusher tug and the barge remain so connected throughout the voyage.

(2) Pusher tug-barge combination connected in articulated manner is a combination of a pusher tug and a barge with the following characteristics:

① the pusher tug is secured in the barge notch by mechanical means of any type whatsoever other than just wire ropes, chains, lines or other tackles;

② the articulated connector allows pitch between the pusher tug and the barge in one degree of freedom, i.e. rotation of the pusher tug/barge about the (transverse) axis of the connector. The combination is capable of being connected or disconnected remotely from the pusher tug or locally from the barge. The pusher tug and the barge remain so connected throughout the voyage;

③ when the articulated connector is disconnected, both the pusher tug and the barge may remain separately in mooring or operation.

(3) Length of combination (L_c) means the length of the pusher tug-barge combination acting as a single unit. The combined length L_c is to be taken as the distance, in m, measured on a waterline at 85% of the least molded depth of the barge (where the lowest point of freeboard deck of the pusher tug is at or above this waterline) or on the design waterline of the combination (where the lowest point of freeboard deck of the pusher tug is below this waterline), from the fore side of the stem of the barge to the after side of the rudder post or stern post of the pusher tug. Where there is no rudderpost or stern post, L_c is to be measured to the centerline of the rudder stock of the pusher tug. L_c, however, is not to be taken less than 96% and need not be taken greater than 97% of the total waterline length of the combination measured at 85% of the least molded depth of the barge.

7.2.1.3 In addition to the plans and documents required for pusher tugs and barges acting as single vessels in the Rules, the following ones are to be submitted to ISC for approval:

(1) Plan of strengthened hull structural portions in way of the connection of tug and barge for each vessel.

7.2.1.4 The following plans and documents are to be submitted to ISC for information:

(1) Provision and arrangement of connector of the combination;

(2) Connector load calculations;

(3) Diagram of mechanical principles of the connector;

(4) Analysis calculations of strengthened hull structural portions in way of the connection of tug and barge for each vessel;

(5) Operating manual for the connector, including instructions on operation, testing and maintenance.

7.2.1.5 Class notations are as follows:

(1) A rigidly connected pusher tug-barge combination complying with this Section is to be assigned the following class notations:

For pusher tug: Rigid Connection PB Combination — Pusher;
For barge: Rigid Connection PB Combination — Barge.

(2) An articulatedly connected pusher tug-barge combination complying with this Section is to be assigned the following class notations:

For pusher tug: Articulated Connection PB Combination — Pusher;
For barge: Articulated Connection PB Combination — Barge.

7.2.2 Freeboard, subdivision and stability, bilge pumping system

7.2.2.1 The freeboard, subdivision and stability, bilge pumping system of a pusher tug-barge combination

acting as a single unit and of pusher tugs and barges acting as single vessels are to comply respectively with the following requirements or the relevant requirements of the flag Administration (if any):
(1) The freeboard, subdivision and stability, bilge pumping system of pusher tugs and general barges acting as single vessels are to comply with the relevant requirements of the flag Administration.
(2) The freeboard, subdivision and stability, bilge pumping system of open-hatch container barges are to comply with the requirements for open-hatch container ships in Section 2 of this Chapter.
7.2.2.2 Freeboard and arrangement requirements are as follows:
(1) In addition to the requirements in 7.2.2.1(1), the freeboard and bow height of a barge are not to be less than those required for the combination acting as a single unit (general cargo ship).
(2) In all cases, a safe passage is to be available for crew between the aft part of the barge and the fore part of the pusher tug.
7.2.2.3 The intact stability of a combination acting as a single unit in full load condition (fully loaded pusher tug + fully loaded barge) is to comply with the requirements for general cargo ships.

7.2.3 Hull structure and outfitting

7.2.3.1 Requirements for hull structure are as follows:
(1) Hull structure of pusher tug
① A pusher tug acting as a single ship is to comply with the requirements for tugs specified in Chapter 10 of PART TWO of the Rules.
② When calculating the wave impact loading of superstructures and deckhouses, they are to be considered as those of the combination. However, the thickness of their decks and enclosures need not be greater than that of the main hull shell or deck of the pusher tug.
(2) Hull structure of barge
① A barge acting as a single ship is to comply with the requirements of Chapter 12 of PART TWO of the Rules.
② The collision bulkhead of the barge is to be located according to the length of combination L_c, i.e. at a distance, from the fore end of the barge, of not less than 0.05 L_c or 10 m, whichever is the lesser, and not more than 0.08 L_c.
③ Both the longitudinal and local strength of open-hatch container barges are to comply with the relevant requirements in Section 1 of this Chapter.
7.2.3.2 Requirements for outfitting are as follows:
(1) Outfitting of pusher tug
① A pusher tug acting as a single ship is to be provided with the anchoring and mooring equipment used for pusher tugs in accordance with the requirements for cargo ships specified in Chapter 3 of PART TWO of the Rules.
② The combination is to be considered as a single unit with regard to the rudder and steering gear to be provided on board.
(2) The combination is to be considered as a single unit with regard to the outfitting of the barge, and the anchoring and mooring equipment may be provided in accordance with the requirements for cargo ships specified in Chapter 3 of PART TWO of the Rules.

7.2.4 Electrical installations

7.2.4.1 The electrical installations of pusher tugs and barges are to comply with the applicable requirements of PART FOUR of the Rules and in addition, the requirements of this Section.
7.2.4.2 Requirements for pusher tugs are as follows:
(1) The calculation of power plant load of the pusher tug is to include the power consumption of the barge.
(2) The navigation bridge of the pusher tug is to be capable of initiating the following alarms on the barge:
① audible and visual alarm in case of high bilge level in hold of barges;
② audible and visual alarm in case of fault of any ship light on barges.
7.2.4.3 Requirements for barges are as follows:
(1) The barge may be served by the power plant of the pusher tug to which the barge is connected, and when at a port of call by a source on shore, as follows:
① A connection box is to be fitted at a suitable place on board the pusher tug for a flexible cable supplying power to the barge.
② A shore connection box complying with the relevant requirements of rules is to be fitted at a suitable place on board the barge for a flexible cable from an external power source. The shore connection box and the main switchboard on board the barge are to be connected by a fixed and

adequately rated cable.

(2) The barge is to be provided with accumulator batteries as standby power source for anchor lights in case of loss of power when anchoring separately. The power supply period of the batteries may be evaluated according to the possible duration of such case.

(3) Where refrigerated containers are carried in the barge, the power plant capacity calculation, power distribution, monitoring, socket type, etc. are to comply with the relevant requirements of Section 4, Chapter 4 of PART FIVE of the Rules.

7.2.4.4 Other requirements

(1) A multi-core flexible cable may be used to transfer monitoring and alarm signals between the pusher tug and the barge. Such cables are to be connected to the pusher tug and the barge via connector assemblies with a degree of protection of at least IP56.

(2) Means of interlock or alarm are to be used to prevent any damage to the flexible cable linking the pusher tug and the barge in case of disconnection of the connector between the two ships.

7.2.5 Connector and hull supporting structure

7.2.5.1 General requirements

(1) This paragraph contains only requirements for articulated connectors. Equivalent safety design may be used for rigid connectors.

(2) Indicators are to be fitted at the navigation bridge and local operation position to show the disconnected or connected status of the connector, and connecting/disconnecting operations are to be possible.

(3) The mechanical connection means (hereinafter referred to as connector) means the mechanical system used on the pusher tug for quick connection with the barge, including a telescopic connecting arm and all associated power and control parts.

(4) The connector is to be capable of being operated both locally and at the navigation bridge, and disconnected in less than 5 minutes in an emergency.

(5) The connector is to be capable of being operated at one side and at both sides.

(6) At least two separate power units are to be provided to serve the connector.

(7) An emergency disconnection of the connector is to be possible in case of loss of power.

(8) Means of communication are to be available between the space where the connector is located and the navigation bridge.

(9) The connector is to be fitted with a limiter to prevent the connecting arm from excessively stretching or retracting.

(10) For hydraulic connectors, the drawings and documents to be submitted, installing and arrangement, materials, structure and design, safety valve, monitoring and alarm, testing (including sea trial) may be dealt with in accordance with the appropriate requirements for steering gears specified in Chapter 13 of PART THREE of the Rules.

(11) The non-hydraulic connectors are to meet a standard equivalent to that for hydraulic ones.

7.2.5.2 Requirements for strength of connector and hull supporting structure

(1) Connector load

① The design of the connector is to take into account the quasi-static loads, including the buoyancy and propulsion forces, and the dynamic seaway loads, as well as the steering loads. The loads may be obtained either according to ② below or by model test, or calculated by an empirical method. The calculation results are to be submitted to ISC for check.

② The maximum lifetime connector loads may be used for the design of the connection system between the tug and barge. The maximum lifetime value is to be determined based on a prediction method for the long-term extreme value with an acceptable probability level. The methods of determining the maximum lifetime connector loads can be identified:

a) through a scale model test program covering a range of wave frequencies and headings so as to obtain the connector load response amplitude operators (RAOs) and then by analysis to identify the worst heading and predict the long term extreme connector load for that heading, or

b) by a motion response analysis, using a suitable sea keeping analysis program that can handle multiple bodies linked by articulation, in connection with a long term extreme analysis, and taking the wave data of the sea area where the pusher tug-barge combination is to operate into calculation.

③ The design calculation of the connector loads is to be documented and submitted for information.

(2) Specification of the connector system is to be submitted for information together with the design load calculations for the connector loads.

(3) Structure and strength of connection means

① Stress analysis is to be performed according to the load stated in 7.2.5.2(1) above to obtain loads acting on individual components of the connector. Strength calculations are to be provided for essential components of the system in accordance with the following criteria:

$$\sigma \le \frac{R_{eH}}{n}$$

$$\tau \le \frac{0.58R_{eH}}{n}$$

where: σ — positive stress, in N/mm^2;
R_{eH} — yield stress of material of components, in N/mm^2;
τ — shear stress, in N/mm^2;
n — safety factor, taken as 2.5.

② For components subjected to composite stress, the equivalent stress is to comply with the following formula:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \le 1.1\frac{R_{eH}}{n}$$

where: σ_e —equivalent stress, in N/mm^2;
R_{eH}, σ, τ, n — the same as above.

(4) Main hull supporting structure and strength

① For the supporting structure of the means connecting the pusher tug and the barge, stress analysis is to be performed in respect to the load transmitted by the connector. The analysis is to follow the conventional engineering practice and is to be submitted for check. The connector loads applied are to be in accordance with the loads determined from 7.2.5.2(1) above. In the case of notch type connections, an analysis of the barge wing walls is to take into account torsional shear as well as primary and secondary shear and bending stresses. The results of the structural analysis are to be assessed for yielding and buckling failures.

② The structure in the bow of the pusher tug and the stern of the barge is to be suitably reinforced both in the athwart ship and fore and aft directions with a system of webs, stringers, bulkheads, etc. to withstand the forces developed at these locations due to the connection and also to transmit these forces into the main body of the ships. The hull structure adjacent to the connector is to be suitably reinforced, and assessed by fine finite element direct calculation. The fine finite element model is to be based on the following principles:

a) a separate fine finite element model may be used, with boundary conditions being obtained from analysis of a coarse finite element model; alternatively, direct calculation may be performed via a fine finite element model fitted in a coarse finite element model;

b) the fine finite element area is to be such that stress of the area will not be affected by the boundary conditions of displacement and those of forces. The fine finite element model is to be such that its refined edges are supported by primary members, e.g. girders, horizontal girders and floors in cargo area;

c) the size of meshes of the fine finite element area adjacent to the connector is to be taken as 50 mm × 50 mm. 4-node or 8-node hull elements are to be used, and the use of any triangular element is to be prevented. The weld geometry and structural alignment are not to be taken into account;

d) the permissible yield stress of structural members are to be in accordance with Table 7.2.5.2(4);

e) buckling assessment may be carried out in accordance with the methods provided in Section 5, Chapter 1, PART TWO of the Rules.

Permissible Equivalent Yield Stress [σ_e]① (N/mm^2) **Table 7.2.5.2(4)**

Model / Element	Local fine finite element model (based on 50 mm × 50 mm mesh size)
Plate element	1.36 R_{eH} (single element)② 1.0 R_{eH} (area average)③

Notes: ① The plate element is to be considered according to the equivalent stress (Von Mises stress), i.e.:

$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$ N/mm^2, the median plane stress at centroid of the plate element (membrane stress) is to be considered

where: σ_x — element stress in x direction, in N/mm^2;
σ_y — element stress in y direction, in N/mm^2;
σ_{xy} — element shear stress in xy plane, in N/mm^2.

② R_{eH}— yield stress of material, in N/mm^2.

③ The area average means the average of the Von Mises stress of the element considered in the fine finite element area and that of the element in the connecting node.

Section 3 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS

7.3.1 General provisions

7.3.1.1 Ships specialized in carrying melted petroleum asphalt in bulk in restricted service are to be in accordance with relevant requirements of Chapter 10 of PART EIGHT of the Rules.

Section 4 DYNAMIC POSITIONING SYSTEMS

7.4.1 Environmental conditions

7.4.1.1 For vessels engaged in restricted service, a long-term distribution of environmental conditions prevailing where the vessel is in operation is to be considered.