GUIDELINES FOR DESIGN AND INSTALLATION OF DUAL FUEL ENGINE SYSTEM

2007

CONTENTS

CHAPTER 1 GENERAL

1.1 Application

1.1.1 The Guidelines is applicable to dual fuel engines which use natural gas (LNG cargo vapour and boil-off gases) and oil fuel as fuel and to its gas fuel supply piping system.
1.1.2 In addition to complying with the requirements of the Guidelines, dual fuel engines and its gas fuel supply piping system are to be in compliance with ISC Rules for Classification of Sea-Going Steel Ships (hereinafter referred to as ISC Rules for Steel Ships), ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (hereinafter referred to as ISC Rules for Liquefied Gas Carriers).

1.2 Definition

1.2.1 For the purpose of the Guidelines:
(1) Dual fuel engines are engines that can burn natural gas (pilot fuel oil needed to be injected for ignition) and fuel oil simultaneously or independently.
(2) Dual fuel engine compartment is an independent machinery space which is located within the engine room for installation of dual fuel engines.
(3) High pressure piping is the gas fuel piping with maximum working pressure above 1MPa.
(4) Low pressure piping is the gas fuel piping with maximum working pressure not exceed 1MPa.
(5) Interlocked gas valves (double block and bleed valve) is a set of three automatic valves located at the fuel supply to each of the gas engines. Two of these valves are to be in series in the gas fuel pipe to the engines. The third valve is to be in a pipe that vents to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series.
(6) Master gas fuel valve is an automatic valve in the gas fuel supply line which is to be situated in the cargo area and be capable of being remotely controlled.
(7) Natural gas is a gas without condensation at common operating pressures and temperatures (20? and 1atm) were the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).
(8) Pilot fuel oil is used for igniting methane-air mixture in cylinder.

1.3 Plans and documents

1.3.1 Plans and documents of dual fuel engine are to be submitted according to the requirements in Chapter 9, PART THREE of ISC Rules for Steel Ships. Additional plans and documents to be submitted for approval are as follows:
(1) Gas fuel injection valve with its actuating and sealing system;
(2) Arrangement and details of crankcase protection;
(3) Arrangement of explosion protection for air inlet manifolds and for exhaust manifolds including size calculations;
(4) Engine control system diagram (including monitor, safety and alarm systems) for gas fuel combustion operation;
(5) Failure Modes and Effects Analysis (FMEA);

(6) Procedures for shipboard trial;
(7) Other plans and documents as deemed necessary by ISC.

1.3.2 Plans and documents of dual fuel engine compartment/room and gas fuel piping system for approval are as follows:

(1) General arrangement of dual fuel engine compartment/room, including location of the gas detectors;
(2) General arrangement of electrical equipment and lighting of dual fuel engine compartment/room;
(3) Ventilation system for dual fuel engine compartment/room. For dual fuel engine compartment/ room specified in 2.1 of the Guidelines, calculations of ventilation capacity are also to be included;
(4) Fixed gas detection and alarm systems, and associated shut-off and shutdown systems;
(5) Gas fuel piping system and protective device for gas leak from them (including details of pipes and associated components, size, type, design pressures and temperatures);
(6) Automatic control and remote control systems for gas fuel supply systems;
(7) Details of all electrical equipment in the dual fuel engine compartment/room (for information);
(8) Other plans and documents as deemed necessary by ISC.

1.4 Shipboard trial

1.4.1 Dual fuel engine is in general to be subject to tests in accordance with the relevant provisions in Chapter 9, PART THREE of ISC Rules for Steel Ships, operating, control, alarm and safety protection associated with the use of gas fuel are to be verified during the test.

CHAPTER 2 DUAL FUEL ENGINE COMPARTMENT/ROOM

2.1 Dual fuel engine compartment with single-wall gas fuel supply piping

2.1.1 This Section applies to dual fuel engine compartment with single-wall gas fuel supply piping.
2.1.2 Dual fuel engine compartment with single-wall gas fuel supply piping is to comply with the following requirements:
(1) Maximum working pressure in gas fuel supply lines in the dual fuel engine compartment is not to exceed 1 MPa.
(2) Dual fuel engines are to be located in two or more separate dual fuel engine compartments. In the case of emergency shutdown of any one of the dual fuel engine compartments due to the failures specified in 5.3.1 of Chapter 5 of the Guidelines, it must be possible to maintain at least the following speed for sea going services:
7 kn or half of the design speed, whichever is lesser.
(3) Dual fuel engine compartment is to only contain dual fuel engine(s) and minimum necessary equipment, incinerators, inert gas generators or other oil-fired boilers are not to be installed within dual fuel engine compartment.
(4) Dual fuel engine compartment is to be as small as possible and be arranged in such a way as to prevent the formation of dead spaces for facilitating ventilation and gas detection without compromising maintainability.
2.1.3 Ventilation system is to comply with the following requirements:
(1) Each dual fuel engine compartment is to be fitted with at least two mechanical ventilation fans with a total capacity of at least 30 air changes per hour based on the gross volume of the compartment, taking into consideration the combustion air required for the engine(s) in the compartment if the air intakes of the engine is located within dual fuel engine compartment.
If one fan is out of service, the capacity of the remaining ventilation fan(s) is to be not less than 100% of the total required.
(2) Ventilation ducting is to be situated in the dual fuel engine compartment in such a manner as to ensure immediate evacuation of the leaked gas from the entire compartment.
(3) The ventilation system in each dual fuel engine compartment is to be separated from those intended for other spaces including other dual fuel engine compartments.
(4) The ventilation inlet and discharge are to be respectively from and to a safe location.
(5) The ventilation fans are to comply with 12.1.9 of ISC Rules for Liquefied Gas Carriers and electric motors for these fans are to be located outside of the ventilation ducts.
(6) The ventilation system is to be always in operation when there is gas fuel in the piping while in normal operation, as well as in purging operation prior to maintenance works.
2.1.4 Gas detection systems are to comply with the following requirements:
(1) There are to be at least two independent fixed gas detection systems in each dual fuel engine compartment for continuous monitoring of the presence of leaked gas.
(2) Each gas detection system is to comply with the following requirements:
① gas detection system is to be of the self-monitoring type;
② in the case that a detection system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected with alarm such that the detector fault will not cause false emergency shutdown;
③ the gas detection system is to be so arranged that it provides functional redundancy when either one of the systems fails;
④ the gas detection equipment is to be so designed that it may be readily tested.

(3) The gas detection system is always to be in operation when there is gas fuel in the piping while in normal operation, as well as in purging operation prior to maintenance works.
(4) Placement of the detectors is critical to the effectiveness of the gas detection system. The exact location of the gas detectors is to be determined taking into consideration the sensitivity of gas detectors under the prevailing airflow.
(5) The gas detection systems and the associated emergency shutdown systems are to be tested and maintained to ensure their reliability during working conditions and are to be recalibrated at regular intervals in accordance with the manufacturer's recommendations given in the maintenance and instruction manual. Tests and maintenance procedures are to be documented and kept onboard for the crews' use.
2.1.5 Electrical equipment in the dual fuel engine compartment, which is intended to be operational after the dual fuel engines have been shut down due to a gas leakage, is to be of the certified safe type.
2.1.6 The access to the dual fuel engine compartment is to be arranged in accordance with the following requirements:
(1) Each dual fuel engine compartment is to have at least two completely independent accesses located as far from each other as possible.
(2) The access to the dual fuel engine compartment is to be provided with a self-closing door with alarm that would be initiated when the door remains open for more than 1 min.

2.2 Engine room of which the gas fuel supply piping is installed inside a ventilated duct or is double-wall piping

2.2.1 This Section applies to engine room of which the gas fuel supply piping is installed inside a ventilated duct or is double-wall piping.
2.2.2 Ventilation, arrangement and gas detection of the engine room are to comply with 16.2 of ISC Rules for Liquefied Gas Carriers.
2.2.3 Ventilation inlets is to be from a safe location far from discharge where there is the least possible risk of flammable gas or sparks being drawn into the system.

CHAPTER 3 GAS FUEL PIPING SYSTEM

3.1 General requirements

3.1.1 Gas fuel supply piping system is to comply with the relevant requirements in 5.2 to 5.5 of ISC Rules for Liquefied Gas Carriers.
3.1.2 Gas fuel piping system leading to dual fuel engine compartment/room is not to pass through accommodation spaces, service spaces or control stations. Gas fuel piping system may pass through or extend into other spaces provided they fulfill the requirements of 3.3.1 or 3.3.2 of this Chapter.
3.1.3 Gas fuel piping which are on the open deck outside the cargo area is to have full penetration butt-welded joints and is to be fully radiographed.
3.1.4 Provision is to be made for inerting and gas-freeing the gas fuel piping system.
3.1.5 A system for colour marking of all gas pipes is to be used and the arrangement of the piping is to prevent external damage.
3.1.6 Each dual fuel engine is to be provided with a set of three automatic valves and to comply with the following requirements:
(1) Two of these valves are to be in series in the gas fuel pipe to the engine. The third valve is to be in a pipe that vents that portion of the gas fuel piping between the two valves in series, to a safe location in the open air.
(2) These valves are to be arranged so that when relevant failure is initiated as specified in Tables 5.2.1, 5.3.1 of the Guidelines, this will cause the two gas fuel valves, which are in series, to close automatically and the vent valve to open automatically.
(3) Alternatively, the function of one of the valves in series and the vent valve can be incorporated into one valve body so arranged that when relevant failure is initiated as specified in Tables 5.2.1, 5.3.1 of the Guidelines, flow to the engine will be blocked and the vent opened.
(4) The three shut-off valves are to be arranged for manual reset.
(5) The two valves in series are to be of the fail-closed type and the vent valve is to be of the fail-open type.
3.1.7 At least one master gas fuel valve is to be provided in the gas fuel pipe within the cargo area and to comply with the following requirements:
(1) The master gas fuel valve can be closed from within and outside the engine compartment/room and at the bridge control station.
(2) The valve is to be arranged so as to close automatically to shut off gas flow to the engine if the relevant failure specified in Tables 5.2.1, 5.3.1 of the Guidelines occurs.
3.1.8 A local manual closing device is to be provided on the gas fuel piping of each dual fuel engine so as to shut off gas flow to the engine safely during maintenance of the engine.
3.1.9 If a gas leak occurs, the gas fuel supply is not to be restored until the leak has been found and repaired. Instructions to this effect are to be placed in a prominent position in the dual fuel engine compartment/room.

3.2 Single wall gas fuel piping within dual fuel engine compartment

3.2.1 The maximum working pressure in the gas fuel piping in the dual fuel engine compartment is not to exceed 1 MPa.
3.2.2 The design pressure of gas fuel piping is to be not less than 1 MPa.
3.2.3 Joints are to be kept to a minimum and are to be of full penetration butt-welded type.

3.2.4 Where connections are needed for maintenance purposes, these are to be of the welded neck flange type (type A flange). The welded connections are to be examined using 100% radiographic tests.

3.3 Gas fuel piping which is double wall piping system or installed inside a ventilated duct within dual fuel engine room

3.3.1 Gas fuel piping which is double wall piping is to comply with 16.3.1(1) of ISC Rules for Liquefied Gas Carriers. Where high pressure gas is carried in the inner pipe, it is also to comply with 1.9 of Appendix 1 in Chapter 9, PART THREE of ISC Rules for Steel Ships.

3.3.2 Gas fuel supply piping which is to be installed within a ventilated pipe or duct is to comply with 16.3.1 (2) of ISC Rules for Liquefied Gas Carriers. Where high pressure gas is carried in the gas fuel piping, it is also to comply with 1.9 of Appendix 1 in Chapter 9, PART THREE of ISC Rules for Steel Ships.

3.3.3 For high-pressure piping the design pressure of the ducting specified in 3.3.2 is to be taken as the higher of the following:

(1) the maximum built up pressure: static pressure in way of the rupture resulting from the gas flowing in the ventilated duct;

(2) local instantaneous peak pressure in way of the rupture P_c, is given by the following expression:

$$P_c = P_0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where: P_0 —— maximum working pressure of the inner pipe;

k —— $k = C_p / C_v$ constant pressure specific heat divided by the specific volume specific heat, k = 1.31 for CH_4.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1.5 ($R_m/1.5$), (R_m, the tensile strength of material) when subjected to the above pressure. As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports are then to be submitted.

3.3.4 For low pressure piping the duct specified in 3.3.2 is to be dimensioned for a design pressure not less than that of the gas pipes. The duct is also to be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

3.3.5 The double wall piping system or the ventilated pipe or duct provided for the gas fuel piping is to terminate at the ventilation hood or casing required by 3.3.6 of this Chapter.

3.3.6 A ventilation hood or casing is to be provided for the areas occupied by flanges, valves, etc., and for the gas fuel piping, at dual fuel engine. If this ventilation hood or casing is not served by the exhaust ventilation fan serving the ventilated pipe or duct as specified in 3.3.2 of this Chapter, then it is to be equipped with an exhaust ventilation system and continuous gas detection is to be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with 3.3.9 of this Chapter. The master gas fuel valve required by 3.1.7 of this Chapter is to close automatically if the required air flow is not established and maintained by the exhaust ventilation system.

The ventilation hood or casing is to be installed or mounted to permit the ventilating air to sweep across the gas utilization unit and be exhausted at the top of the ventilation hood or casing.

3.3.7 For dual fuel engine with high pressure gas injection, the connecting of gas line and double wall or ducts regulated in 3.3.1, 3.3.2 of this Chapter to the gas fuel injection valves are to provide complete coverage by the double wall or ducting, and the arrangement of the ventilation hood or casing required by 3.3.6 of this Chapter can be omitted.
3.3.8 The ventilation inlet and discharge for the ventilation systems as required by this Chapter are to be respectively from and to a safe location.
3.3.9 Gas detection systems as required by 3.3.2 and 3.3.6 of this Chapter are to comply with the relevant requirements in Chapter 13 of ISC Rules for Liquefied Gas Carriers.

3.4 Gas valve unit

3.4.1 Where GVU is located in a dedicated compartment, the safety principles and arrangements of that compartment (i.e., the ventilation system, gas detection, electrical equipment, access arrangements) are to be the same as those required for a dual fuel engine compartment with single-wall gas piping in 2.1.3 to 2.1.6 of the Guidelines.

CHAPTER 4 DUAL FUEL ENGINE

4.1 General requirements

4.1.1 In addition to complying with the requirements of this Chapter, dual fuel engines are to be in compliance with the relevant provisions of Chapter 9, PART THREE of ISC Rules for Steel Ships.
4.1.2 Engines are to be of the compression-ignition, dual fuel type using oil fuel or natural gas as fuel.
4.1.3 Small amount of pilot fuel oil is used for ignition of gas fuel while using natural gas as fuel.
4.1.4 Engines are to be capable of immediate change-over to either fuel. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply mentioned above without interruption to propulsion or power supply.
4.1.5 Only oil fuel is to be used prior to a normal stop, and when starting the engine and in low power operation.
4.1.6 Only oil fuel is, in principle, to be used when the operation of an engine is unstable, and/or during manoeuvring and port operations.

4.2 Arrangement

4.2.1 The installation arrangements of the gas fuel piping are to provide the necessary flexibility to accommodate the oscillating movements of the engine without risk of fatigue failure in the piping connections to the engine.
4.2.2 Where air intakes are located inside the engine compartment, these are to be situated as far apart as practicable from the gas fuel supply pipe such that, in the event of a gas leak, the risk of the gas entering the intake is minimized.
4.2.3 Gas fuel injection valves are to be provided with necessary measures to effectively prevent gas fuel from leaking through spaces around valve spindles or gas fuel valves.

4.3 Protection of starting air and air intakes

4.3.1 Starting air branch pipes to each cylinder are to be provided with flame arresters.
4.3.2 Explosion relief valves or other appropriate protection system against explosion are to be provided in the air inlet or scavenge manifolds. The arrangement and location of the protection devices is to be such as to minimize the dangers from the emission of the flame. Alternatively, documentation may be submitted for consideration showing that the system has sufficient strength to withstand a worst-case explosion, the requirements of the protection devices against explosion mentioned above may be dispensed with.

4.4 Protection of crankcase

4.4.1 For dual fuel engine with high pressure gas injection, relief valves of an approved type are to be provided for the crankcase at every crankthrow, and for separate spaces on the crankcase such as gear or chain cases for camshaft or similar drives. The construction and operating pressure of the relief valves are to be determined considering explosions due to gas leaks.
4.4.2 If a trunk piston type engine is used as dual fuel engine, the crankcase is to be protected by the following measures:

(1) Independent ventilation is to be provided for the crankcase of each engine and the gas arrangements are to be made so that any blow-by gas may readily reach the vent which is to be led to a safe location in the open through flame arrester.
(2) A means are to be provided for inerting and gas-freeing the crankcase before opening the crankcase doors.
(3) The crankcase is to be protected by an oil mist detector and gas detecting or equivalent equipment which are to be of the certified safe type. Gas detectors are to be provided and may be located in the crankcase vent pipe. The gas detector is to be provided with adequate arrangement to protect it from oil mist contamination.
4.4.3 If a cross-head type engine is used as dual fuel engine, the crankcase is to be protected by oil mist detector or bearing temperature detector.
4.4.4 The warning notice required by 9.7.12 of PART THREE of ISC Rules for Steel Ships is to include a caution that the crankcase is not to be opened until adequate precautions have been taken to ensure that no gas remains trapped in the crankcase.

4.5 Protection for piston underside space

4.5.1 If a cross-head type engine is used as dual fuel engine, the piston underside space is to be protected by gas detecting or equivalent equipment which are to be of the certified safe type.

4.6 Ventilation

4.6.1 Where a dry lubricating oil sump is used, the vent from the lubricating oil tank is to be led to a safe location in the weather through a flame arrester.
4.6.2 To safely vent any fuel gas that may enter the dual fuel engine cooling water system, the cooling water expansion tank vent is to be led through a flame arrester to a safe location in the weather.

4.7 Exhaust system

4.7.1 Explosion relief valves and or other appropriate protection against explosion are to be provided on the exhaust manifolds. The arrangement and location of the protective devices is to minimize the dangers from emission of flame. Alternatively, documentation may be submitted for consideration showing that the system has sufficient strength to withstand a worst-case explosion, the requirements of the protection devices against explosion mentioned above may be dispensed with.
4.7.2 The exhaust gas pipes from dual fuel engines are not to be connected to the exhaust pipes of other engines or systems.
4.7.3 Installation arrangements are to have the exhaust pipes sloped upwards after the turbocharger in order to avoid formation of gas pockets.
4.7.4 Means are to be provided to discharge the gas that may be present in the exhaust system.

CHAPTER 5 CONTROL, MONITORING AND SAFETY SYSTEMS

5.1 General requirements

5.1.1 In addition to complying with the requirements of this Chapter, the control, monitoring and safety system of dual fuel engine and its gas fuel supply is to be in compliance with the relevant provisions of Chapter 9, PART THREE and PART SEVEN of ISC Rules for Steel Ships.

5.2 Monitoring and safety system functions for dual fuel engine

5.2.1 The control, monitoring and safety system functions for dual fuel engine are to comply with Table 5.2.1.

Monitoring and safety system functions for dual fuel engine Table 5.2.1

Monitored parameters	Alarm	Automatic activation of the double block and bleed valves	Automatic switching over to oil fuel mode	Engine shutdown
Gas fuel injection systems — malfunction	X	X	X	
Pilot oil fuel injection systems — malfunction	X	X	X	
Exhaust gas after each cylinder, temperature — high	X	X	X	
Exhaust gas after each cylinder, deviation from average, temperature — high	X	X	X	
Cylinder ignition — failure	X	X	X	
Oil mist in crankcase, mist concentration or bearing temperature — high①	X	X		X
Engine stops — any cause	X	X		

Abbreviations: X Applicable.

Notes: ① For cross head engines slow down can be accepted.

5.2.2 The alarms required by Table 5.2.1 are to be provided at the engine control station. In addition, a group alarm is to be provided at the navigation bridge.

5.2.3 A failure mode and effect analysis (FMEA) examining all possible faults affecting the combustion process is to be submitted.

5.3 Monitoring and safety system functions for gas fuel supply system

5.3.1 Alarm and safety system functions for gas fuel supply systems is to comply with table 5.3.1.

Monitoring and safety system functions for gas fuel supply systems Table 5.3.1

Monitored parameters	Alarm	Automatic shut-off of the master gas fuel valve and the double block and bleed valves	Automatic switching over to oil fuel mode	Compartment Shutdown
Loss of ventilation in dual fuel engine compartment①	X	X	X	
Abnormal pressures in the gas fuel supply line	X	X	X	
Failure of block and bleed valves	X	X②	X	
Failure of master gas fuel valve	X	X	X	
Loss of inert gas overpressure between double wall gas fuel supply piping system and concentric pipes as specified in 3.3 of the Guidelines	X	X	X	
Loss of ventilation in ventilated pipe or duct as specified in 3.3 of the Guidelines	X	X	X	
Fire in dual fuel engine compartment/room	X	X		
Leaked gas concentration reaches 30% LEL③ in ventilated pipe or duct as specified in 3.3 of the Guidelines	X			
Leaked gas concentration reaches 60% LEL③ in ventilated pipe or duct as specified in 3.3 of the Guidelines	X	X		
Leaked gas concentration reaches 30% LEL③ in dual fuel engine compartment①	X			
Leaked gas concentration reaches 60% LEL③ in dual fuel engine compartment①	X	X		X④

Abbreviations: X Applicable.

Notes: ① Dual fuel engine compartment as specified in 2.1 of the Guidelines.

② Only double block and bleed valves to activate.

③ LEL: Lower explosive limit.

④ When a gas leakage is detected in a dual fuel engine compartment, and before the gas concentration detected reaches 60% of the LEL, all the electrical equipment inside the compartment, other than certified safe type, is to be automatically isolated from its electrical supply and all the engines in that compartment are to be shut down.

5.3.2 The alarms required by Table 5.3.1 are to be provided at the engine control station. In addition, a group alarm is to be provided at the navigation bridge.

5.3.3 Where dual fuel engines arranged in accordance with 2.1 of the Guidelines are used for electric propulsion power generation, effective measures are to be provided to safeguard the power supply system from overloading, which may occur due to the sudden shutdown of a dual fuel engine compartment.