INTERNATIONAL SHIP CLASSIFICATION

GUIDELINES FOR TESTING AND SURVEY OF EMISSION OF NITROGEN OXIDES FROM MARINE DIESEL ENGINES

2020

CONTENTS

Chapter 1 General

1.1 Purpose

1.1.1 The Guidelines for Testing and Survey of Emission of Nitrogen Oxides from Marine Diesel Engines (hereinafter referred to as the Guidelines) have been revised for the implementation of regulation 13 of MARPOL Annex VI — Regulations for the Prevention of Air Pollution from Ships (resolution MEPC.176(58)) and Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (resolution MEPC.177(58)), as revised in 2008.

1.1.2 The Guidelines are used for testing and survey of emission of nitrogen oxides from marine diesel engines by International Ship Classification (hereinafter referred to as ISC) upon an authorization by the Administration or upon a request by clients. The Guidelines may also provide general methods and guidance for diesel engine manufacturers, shipbuilders or ship owners to carry out tests (including test-bed testing and onboard testing) of emission of nitrogen oxides from marine diesel engines.

1.2 Application

1.2.1 The Guidelines apply to diesel engines requesting for EIAPP Certificate (or Statement of Compliance) of ISC.

1.3 Definitions and abbreviations

1.3.1 Definitions

(1) Ship means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms.

(2) Ship constructed means a ship the keel of which is laid or which is at a similar stage of construction.

A similar stage of construction means the stage at which:

① construction identifiable with a specific ship begins; and

② assembly of that ship has commenced comprising at least 50 tonnes or one per cent of the estimated mass of all structural material, whichever is less.

(3) Nitrogen Oxide (NO_x) emissions means the total emission of nitrogen oxides, calculated as the total weighted emission of NO_2 and determined using the relevant test cycles and measurement methods as specified in the Guidelines.

(4) Substantial modification of a marine diesel engine means:

① For engines installed on ships constructed on or after 1 January 2000, substantial modification means any modification to an engine that could potentially cause the engine to exceed the emission standards set out in regulation 13 of Annex VI. Routine replacement of engine components by parts specified in the Technical File that do not alter emission characteristics is not to be considered a "substantial modification" regardless of whether one part or many parts are replaced.

② For engines installed on ships constructed before 1 January 2000, substantial modification means any modification made to an engine which increases its existing emission characteristics established by the Simplified Measurement method as described in 6.3 in excess of the allowances set out in 6.3.11. These changes include, but are not limited to, changes in its operations or in its technical parameters (e.g., changing camshafts, fuel injection systems, air systems, combustion chamber configuration, or timing calibration of the engine). The installation of a certified Approved Method pursuant to regulation 13.7.1.1 or certification pursuant to regulation 13.7.1.2 of MARPOL Annex VI is not considered to be a substantial modification.

(5) Components are those interchangeable parts which influence the NO_x emissions performance, identified by their design/parts number.

(6) Setting means adjustment of an adjustable feature influencing the NO_x emissions performance of an engine.

(7) Operating values are engine data, like cylinder peak pressure, exhaust gas temperature, etc., from the engine log which are related to the NO_x emission performance. These data are load-dependent.

(8) Administration means the Government of the State under whose authority the ship is operating. With respect to a ship entitled to fly a flag of any State, the Administration is the Government of that State. With respect to fixed or floating platforms engaged in exploration and exploitation of the sea-bed and subsoil thereof adjacent to the coast over which the coastal State exercises sovereign rights for the purposes of exploration and exploitation of their natural resources, the Administration is the Government of the coastal State concerned.

(9) Onboard NO_x verification procedures mean a procedure, which may include an equipment requirement, to be used on board at initial certification survey or at the renewal, annual or intermediate surveys, as required, to verify compliance with any of the requirements of the Guidelines, as specified by the applicant for engine certification and approved by ISC.

(10) Marine diesel engine (hereinafter referred to as “diesel engine”) means any reciprocating internal combustion engine operating on liquid or dual fuel, to which regulation 13 of Annex VI applies, including booster/compound systems if applied. In addition, a gas-fuelled engine installed on a ship constructed on or after 1 March 2016 or a gas-fuelled additional or non-identical replacement engine installed on or after that date is also considered as a marine diesel engine.

Where an engine is intended to be operated normally in the gas mode, i.e. with the gas fuel as the main fuel and with liquid fuel as the pilot or balance fuel, the requirements of regulation 13 have to be met only for this operation mode. Operation on pure liquid fuel resulting from restricted gas supply in cases of failures is to be exempted for the voyage to the next appropriate port for the repair of the failure.

(11) Rated power means the maximum continuous rated power output as specified on the nameplate and in the Technical File of the marine diesel engine to which regulation 13 of Annex VI and the Guidelines apply.

(12) Rated speed is the crankshaft revolutions per minute at which the rated power occurs as specified on the nameplate and in the Technical File of the marine diesel engine.

(13) Brake power is the observed power measured at the crankshaft or its equivalent, the engine being equipped only with the standard auxiliaries necessary for its operation on the test bed.

(14) Onboard conditions mean that an engine is:

① installed on board and coupled with the actual equipment which is driven by the engine; and

② under operation to perform the purpose of the equipment.

(15) A Technical File is a record containing all details of parameters, including components and settings of an engine, which may influence the NO_x emission of the engine, in accordance with 3.4 of the Guidelines.

(16) A Record Book of Engine Parameters is the document used in connection with the Engine Parameter Check method for recording all parameter changes, including components and engine settings, which may influence NO_x emission of the engine.

(17) An Approved Method is a method for a particular engine, or a range of engines, which, when applied to the engine, will ensure that the engine complies with the applicable NO_x limit as detailed in regulation 13.7 of Annex VI.

(18) An Existing Engine is an engine which is subject to regulation 13.7 of Annex VI.

(19) An Approved Method File is a document which describes an Approved Method and its means of survey.

(20) An Emission Control Area is to be any sea area, including any port area, designated by International Maritime Organization in accordance with the criteria and procedures set forth in appendix III to Annex VI.

(21) Defeat device means a device which measures, senses, or responds to operating variables (e.g., engine speed, temperature, intake pressure or any other parameter) for the purpose of activating, modulating, delaying or deactivating the operation of any component or the function of the emission control system such that the effectiveness of the emission control system is reduced under conditions encountered during normal operation, unless the use of such a device is substantially included in the applied emission certification test procedures.

(22) Irrational emission control strategy means any strategy or measure that, when the ship is operated under normal conditions of use, reduces the effectiveness of an emission control system to a level below that expected on the applicable emission test procedures.

(23) Electronic Record Book means a device or system, approved by the ISC, used to electronically record the entries required under this Code in lieu of a hard copy record book.

1.3.2 Abbreviations

(1) 1997 NTC (NO_x Technical Code, 1997) is the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines adopted by resolution 2 of MARPOL 1997. Reference may be made to ISC Guidelines for Testing and Survey of Emission of Nitrogen Oxides from Marine Diesel Engines, 2000.

(2) 2008 NTC (NO_x Technical Code, 2008) is the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines adopted by resolution MEPC.177(58). Reference may be made to the Guidelines for detail.

(3) The EIAPP Certificate is the Engine International Air Pollution Prevention Certificate which relates to NO_x emissions.

(4) The IAPP Certificate is the International Air Pollution Prevention Certificate.

(5) SDR (Special Drawing Right) is created by the IMF (International Monetary Fund) as an international reserve asset and unit of account.

Chapter 2 NO_x Emission Standards

2.1 General requirements

2.1.1 The NO_x emission standards in this Chapter apply to ships engaged in international voyages. For other waters, see relevant regulations for implementation.

2.2 Maximum allowable NO_x emission limits for marine diesel engines

2.2.1 The maximum allowable NO_x emission limit values are given by paragraphs 2.3, 2.4 and 2.5. The total weighted NO_x emissions, as measured and calculated, rounded to one decimal place, in accordance with the procedures in the Guidelines, is to be equal to or less than the applicable calculated value corresponding to the rated speed of the engine.

2.2.2 When the engine operates on test fuel oils in accordance with 5.4, the total emission of nitrogen oxides (calculated as the total weighted emission of NO_2) is to be determined using the relevant test cycles and measurement methods as specified in the Guidelines. However, for Tier I engines installed on ships constructed on or before 31 December 2010, applicable measurement procedures may be selected according to 3.2.

2.2.3 An engine's exhaust emissions limit value, given from the formulae included in Table 2.3 as applicable, and the actual calculated exhaust emissions value, rounded to one decimal place for the engine, is to be stated on the engine's EIAPP Certificate. If an engine is a Member Engine of an Engine Family or Engine Group, it is the relevant Parent Engine emission value that is compared to the applicable limit value for that Engine Family or Engine Group. The limit value given here is to be the limit value for the Engine Family or Engine Group based on the highest engine speed to be included in that Engine Family or Engine Group, irrespective of the rated speed of the Parent Engine or the rated speed of the particular engine as given on the engine's EIAPP certificate.

2.2.4 In the case of an engine to be certified in accordance with Tier III standard the specific emission at each individual mode point specified in 2.6 is not to exceed the applicable NO_x emission limit value by more than 50% except as follows:

(1) The 10% mode point in the D2 test cycle specified in 2.6.4.

(2) The 10% mode point in the C1 test cycle specified in 2.6.5.

(3) The idle mode point in the C1 test cycle specified in 2.6.5.

2.3 Marine diesel engines installed on a ship constructed after 1 January 2000

The operation of a marine diesel engine which is installed on a ship constructed after 1 January 2000 is prohibited, except when the emission of nitrogen oxides from the engine is within the limits specified in Table 2.3, where n = rated engine speed (crankshaft revolutions per minute):

Applicable requirements for the emission of NO_x from marine diesel engines installed on a ship constructed after 1 January 2000 Table 2.3

Date of construction	Emission standard	NO_x emission limits(g/kWh)		
		N<130 rpm	130 rpm $\leq n <$ 2000 rpm	$n \geq$2000 rpm
on or after 1 January 2000 and prior to 1 January 2011	Tier I	17.0	$45 \cdot n^{(-0.2)}$	9.8
on or after 1 January 2011	Tier II	14.4	$44 \cdot n^{(-0.23)}$	7.7
on or after 1 January 2016①	Tier III②	3.4	$9 \cdot n^{(-0.2)}$	2.0

Notes:

① The standards are to apply to a marine diesel engine that is installed on a ship that is constructed on or after 1 January 2016 and is operating in the North American Emission Control Area or the United States Caribbean Sea Emission Control Area; a marine diesel engine that is installed on a ship that is operating in an emission control area other than the North American Emission Control Area or the United States Caribbean Sea Emission Control Area, and is constructed on or after the date of adoption of such an emission control area, or a later date as may be specified in the amendment designating the NO_x emission control area, whichever is later.

② The standards of Tier III are not to apply to:

(a) a marine diesel engine installed on a ship with a length (*L*), as defined in regulation 1.19 of Annex I of MARPOL, less than 24 metres when it has been specifically designed, and is used solely, for recreational purposes; or

(b) a marine diesel engine installed on a ship with a combined nameplate diesel engine propulsion power of less than 750 kW if it is demonstrated, to the satisfaction of ISC, that the ship cannot comply with the standards of Tier III because of design or construction limitations of the ship;

(c) a marine diesel engine installed on a ship constructed prior to 1 January 2021 of less than 500 gross tonnage, with a length (L), as defined in regulation 1.19 of Annex I to the present convention, of 24 m or over when it has been specifically designed, and is used solely, for recreational purposes.

2.4 Marine diesel engines installed on a ship constructed prior to 1 January 2000

2.4.1 **Application**: marine diesel engines with a power output (rated power) of more than 5,000 kW and a per cylinder displacement at or above 90 litres installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000.

2.4.2 **Applicable emission limits**: to comply with Tier I emission limit or the operation of the engine is prohibited.

2.4.3 **Applicable conditions**: an Approved Method for the engine within the application has been certified by an Administration of a Party or the authorized organization and notification of such certification has been submitted to the International Maritime Organization by the certifying Administration and is to be applied no later than the first renewal survey that occurs 12 months or more after deposit of such notification.

2.4.4 **Conditions for delayed compliance**: if a shipowner of a ship on which an Approved Method is to be installed can demonstrate to the satisfaction of the Administration or the authorized organization that the Approved Method was not commercially available despite best efforts to obtain it, then that Approved Method is to be installed on the ship no later than the next annual survey of that ship which falls after the Approved Method is commercially available.

2.4.5 **Requirements for record of IAPP Certificate**: for ships with the application set forth in 2.4.1, the International Air Pollution Prevention Certificate is to, for a marine diesel engine to which this paragraph applies, indicate that either:

(1) an Approved Method has been applied pursuant to the verification procedure specified in the Approved Method File; or

(2) the engine has been certified pursuant to the verification procedures for diesel engines; or

(3) an Approved Method is not yet commercially available as described in paragraph 2.4.4; or

(4) an approved method is not applicable.

2.4.6 **Certification of the engine within the application set forth in 2.4.1** is to be in accordance with 3.6 of the Guidelines.

2.4.7 **Basic conditions for approval of the Approved Method** are to include the following:

(1) verification by the designer of the base marine diesel engine to which the Approved Method applies that the calculated effect of the Approved Method will not decrease engine rating by more than 1.0%, increase fuel consumption by more than 2.0% as measured according to the appropriate test cycle set forth in 2.6 of the Guidelines, or adversely affect engine durability or reliability; and

(2) the cost of an Approved Method is not to exceed 375 Special Drawing Rights/metric ton NO_x calculated in accordance with the Cost-Effectiveness formula below:

$$Ce = \frac{Cost}{\mathrm{T} \cdot P \cdot \Delta NOx} \times 10^6$$

where: Ce — Cost-Effectiveness of an Approved Method, in SDR/t;

Cost — The sale price of the components plus any installation cost above that of regular maintenance, in SDR;

$T = 0.768 \times 6000 \times 5 = 23040$, in h;

P — The rated power (kW) of the engine(s) as defined on the application for an Approved Method, in kW;

ΔNO_x — The difference between the engine's designed weighted specific NO_x value and the applicable limit as stated in Tier I, in g/kWh.

2.5 Marine diesel engines which undergo a major conversion

2.5.1 Major conversion means a modification on or after 1 January 2000 of a marine diesel engine that has not yet been certified to the standards set forth in Table 2.3 where:

(1) an additional marine diesel engine is installed or the engine is replaced by a marine diesel engine (replacement of a marine diesel engine with a non-identical marine diesel engine is excluded), or

(2) any substantial modification, as defined in 1.3.1(4), is made to the engine, or

(3) the maximum continuous rating of the engine is increased by more than 10% compared to the maximum continuous rating of the original certification of the engine.

2.5.2 A marine diesel engine referred to in paragraph 2.5.1(1) is to meet the following:

(1) standards in force at the time the major conversion is made to the engine;

(2) in the case of replacement engines only, if it is not possible for such a replacement engine to meet the standards of Tier III, then that replacement engine is to meet the standards of Tier II.

Note: Refer to the 2013 Guidelines as required by regulation 13.2.2 of MARPOL Annex VI in respect of non-identical replacement engines not required to meet the Tier III limit, adopted by the MEPC by resolution MEPC.230(65).

2.5.3 A marine diesel engine referred to in paragraph 2.5.1(2) or 2.5.1(3) is to meet the following:

(1) for ships constructed prior to 1 January 2000, the standards of Tier I are to apply; and

(2) for ships constructed on or after 1 January 2000, the standards in force at the time the ship was constructed are to apply.

2.6 Test cycles and weighting factors to be applied

2.6.1 For every Individual Engine or Parent Engine of an Engine Family or Engine Group, the relevant test cycles specified in 2.6.2 to 2.6.5 are to be applied for verification of compliance with the applicable NO_x emission limit.

2.6.2 For constant speed marine diesel engines for ship main propulsion, including diesel electric drive and all controllable-pitch propeller installations, test cycle E2 is to be applied.

Test cycle for "Constant-speed main propulsion" application (including diesel-electric drive and all controllable-pitch propeller installations) Table 2.6.2

Test cycle type E2	Speed	100%	100%	100%	100%①
	Power	100%	75%	50%	25%
	Weighting factor	0.2	0.5	0.15	0.15

Note:

① There are exceptional cases, including large bore engines intended for E2 applications, in which, due to their oscillating masses and construction, engines cannot be run at low load at nominal speed without the risk of damaging essential components. In such cases, the engine manufacturer is to make application to ISC that the test cycle as given in Table 2.6.2 above may be modified for the 25% power mode with regard to the engine speed. The adjusted engine speed at 25% power, however, is to be as close as possible to the rated engine speed, as recommended by the engine manufacturer and approved by ISC. The applicable weighting factors for the test cycle are to remain unchanged.

2.6.3 For propeller law operated main and propeller law operated auxiliary engines, test cycle E3 is to be applied.

Test cycle for "Propeller-law-operated main and propeller-law-operated auxiliary engine" application **Table 2.6.3**

Test cycle type E3	Speed	100%	91%	80%	63%
	Power	100%	75%	50%	25%
	Weighting factor	0.2	0.5	0.15	0.15

2.6.4 For constant speed auxiliary engines, test cycle D2 is to be applied.

Test cycle for "Constant-speed auxiliary engine" application **Table 2.6.4**

Test cycle type D2	Speed	100%	100%	100%	100%	100%
	Power	100%	75%	50%	25%	10%
	Weighting factor	0.05	0.25	0.3	0.3	0.1

2.6.5 For variable speed, variable load auxiliary engines, not included above, test cycle C1 is to be applied.

Test cycle for "Variable-speed, variable-load auxiliary engine" application **Table 2.6.5**

Test cycle type C1	Speed	Rated				Intermediate			Idle
	Torque	100%	75%	50%	10%	100%	75%	50%	0%
	Weighting factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15

2.6.6 The torque figures given in test cycle C1 are percentage values which represent for a given test mode the ratio of the required torque to the maximum possible torque at this given speed.

2.6.7 The intermediate speed for test cycle C1 is to be declared by the manufacturer, taking into account the following requirements:

(1) For engines which are designed to operate over a speed range on a full load torque curve, the intermediate speed is to be the declared maximum torque speed if it occurs between 60% and 75% of rated speed.

(2) If the declared maximum torque speed is less than 60% of rated speed, then the intermediate speed is to be 60% of the rated speed.

(3) If the declared maximum torque speed is greater than 75% of the rated speed, then the intermediate speed is to be 75% of rated speed.

(4) For engines which are not designed to operate over a speed range on the full load torque curve at steady state conditions, the intermediate speed will typically be between 60% and 70% of the maximum rated speed.

2.6.8 If an engine manufacturer applies for a new test cycle application on an engine already certified under a different test cycle specified in 2.6.2 to 2.6.5, then it may not be necessary for that engine to undergo the full certification process for the new application. In this case, the engine manufacturer may demonstrate compliance by recalculation, by applying the measurement results from the specific modes of the first certification test to the calculation of the total weighted emissions for the new test cycle application, using the corresponding weighting factors from the new test cycle.

Chapter 3 Surveys and Certification

3.1 General requirements

3.1.1 Types of surveys

3.1.1.1 Survey of diesel engines

Each marine diesel engine specified in 1.2 of the Guidelines is to be subject to the following surveys:

(1) **pre-certification survey** based on test-bed testing of the engine;

(2) survey for engines carried out as part of the ship's **initial certification survey** and **in-service survey** for air pollution prevention according to MARPOL Annex VI;

(3) **initial engine certification survey** carried out after the engine has undergone a major conversion as defined in 2.5.1.

3.1.1.2 Survey of ship for air pollution prevention

Every ship of 400 gross tonnage and above engaged on international voyages is to be subject to the surveys for air pollution prevention including but not limited to the above surveys. An IAPP Certificate valid for a period not exceeding 5 years is to be issued after the satisfactory surveys.

3.1.2 Types of surveys of marine diesel engines

3.1.2.1 A **pre-certification survey** which is to be such as to ensure that the engine, as designed and equipped, complies with the applicable NO_x emission limit contained in chapter 2 of the Guidelines. If this survey confirms compliance, ISC is to issue an Engine International Air Pollution Prevention (EIAPP) Certificate (see Appendix 3 for the format).

3.1.2.2 An **initial certification survey** which is to be conducted on board a ship after the engine is installed but before it is placed in service. This survey is to be such as to ensure that the engine, as installed on board the ship, including any modifications and/or adjustments since the pre-certification, if applicable, complies with the applicable NO_x emission limit contained in chapter 2. This survey, as part of the ship's initial survey, may lead to either the issuance of a ship's initial International Air Pollution Prevention (IAPP) Certificate or an amendment of a ship's valid IAPP Certificate reflecting the installation of a new engine.

3.1.2.3 A **in-service survey** (renewal, annual and intermediate surveys) which is to be conducted as part of a ship's surveys required by regulation 5 of Annex VI, to ensure the engine continues to fully comply with the standards for NO_x emission.

3.1.2.4 An **initial engine certification survey** which is to be conducted on board a ship every time a major conversion, as defined in 2.5.1, is made to an engine to ensure that the engine complies with the applicable NO_x emission limit contained in chapter 2. This will result in the issue, if applicable, of an EIAPP Certificate and the amendment of the IAPP Certificate.

3.1.3 Methods for survey

To comply with the various survey and certification requirements described in 3.1.2, there are methods from which the engine manufacturer, shipbuilder or shipowner, as applicable, can choose to measure, calculate, test or verify an engine for its NO_x emissions, as follows:

(1) **test-bed testing** for the pre-certification survey in accordance with chapter 5;

(2) **onboard testing** for an engine not pre-certificated for a combined pre certification and initial certification survey in accordance with the full test-bed requirements of chapter 5;

(3) **onboard Engine Parameter Check method**, using the component data, engine settings and engine performance data as specified in the Technical File, for confirmation of compliance at

initial, renewal, annual and intermediate surveys for pre-certified engines or engines that have undergone modifications or adjustments to NO_x critical components, settings and operating values, since they were last surveyed, in accordance with 6.2;

(4) **onboard Simplified Measurement method** for confirmation of compliance at renewal, annual and intermediate surveys or confirmation of pre-certified engines for initial certification surveys, in accordance with 6.3 when required; or

(5) **onboard Direct Measurement and Monitoring method** for confirmation of compliance at renewal, annual and intermediate surveys only, in accordance with 6.4.

3.2 Regulations for surveys applicable to Tier I engines

2008 NTC has entered into force on 1 July 2010 with mandatory implementation, and the principles for the survey and certification of Tier I engines installed on ships constructed on or before 31 December 2010 are as follows:

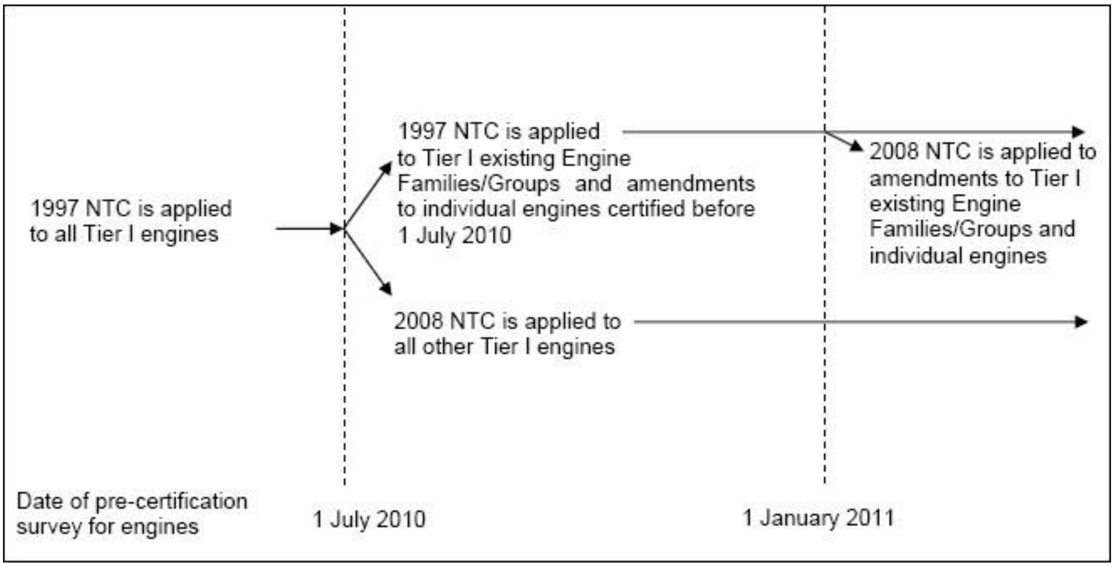

Figure 3.2 Regulations for surveys applicable to Tier I engines

3.2.1 The certification and surveys for Tier I engines are still to be carried out according to 1997 NTC before 1 July 2010.

3.2.2 From 1 July 2010 to 31 December 2010, the survey and certification for Tier I engines are carried out based on the following two situations:

(1) for Tier I existing Engine Families/Groups and individual engines with substantial modification certified before 1 July 2010, the survey and certification may still be carried out according to 1997 NTC; and from 1 January 2011, if:

① no substantial modification is made, 1997 NTC is still to be followed for survey and certification;

② substantial modification is made, 2008 NTC is to be followed for survey and certification.

(2) For Tier I engines not included in (1) above, the survey and certification are to be carried out according to 2008 NTC. And 2008 NTC is to be followed thereafter.

3.3 Application for surveys

3.3.1 The manufacturer, shipbuilder and ship company are to submit application to ISC for the survey as specified in 3.1.2.

3.3.2 The applicant is to make necessary preparation and arrangement before survey and to provide active support according to the Guidelines so as to ensure the work required by ISC are carried out smoothly. The applicant is to introduce the situations faithfully and to provide relevant documents and is responsible for their authenticity.

3.3.3 The applicant is to submit the application with an application form made by ISC or a formal letter:
(1) for pre-certification survey or the survey after modification, the application is to be submitted to the Headquarters, local branch or office;
(2) for in-service survey, the survey requirements of IAPP Certificate are to be followed.

3.3.4 The applicant is to submit the application documents (form or letter) together with relevant technical documents to ISC for review or approval in accordance with the relevant requirements of the Guidelines.

3.4 Pre-certification survey of an engine

3.4.1 The application for pre-certification survey is to be submitted to ISC according to 3.3 together with the following documents and information for review:

(1) details of the product, including engine type, serial number, rated power, rated speed, approved type (Individual Engine, Parent Engine of Family/Group, Member Engine of Family/Group), test cycle, family or group identification, etc.;

(2) components and parameters influencing NO_x emission and their adjustable range, at least including injection nozzle, injection pump, cylinder cover, piston, turbocharger and air cooler;

(3) setting parameters influencing NO_x emissions and their adjustable range such as injection timing, valve timing, compression ratio, etc.;

(4) test programme complying with chapter 5 of the Guidelines (member engine not belonging to Engine Family/Group), see appendix 6 for the details of the programme;

(5) information required by chapter 4 is to be supplied for Parent engine of Engine Family/Group;

(6) name of the testing organization intended to carry out the testing and “Testing Qualification Certificate”. Where the organization is not approved by ISC in special circumstances, the applicant is to report to ISC the basic information of the testing organization for approval according to the applicable requirements of chapter 7 of the Guidelines;

(7) other information deemed necessary by ISC.

3.4.2 Prior to installation on board, every marine diesel engine (Individual Engine), except as allowed by 3.4.3 and 3.4.4, is to:

(1) be adjusted to meet the applicable NO_x emission limit;

(2) have its NO_x emissions measured on a test bed in accordance with the procedures specified in chapter 5 of the Guidelines; and

(3) be pre-certified by ISC, as documented by issuance of an EIAPP Certificate or statement of compliance.

3.4.3 For the pre-certification of serially manufactured engines, depending on the approval of ISC, the Engine Family or the Engine Group concept may be applied (see chapter 4). In such a case, the testing specified in 3.4.2(2) is required only for the Parent Engine(s) of an Engine Family or Engine Group.

3.4.4 Engines not pre-certified on a test-bed

3.4.4.1 There are engines which, due to their size, construction and delivery schedule, cannot be pre-certified on a test bed. In such cases, the engine manufacturer, shipowner or shipbuilder is to make application to ISC requesting an onboard test (see 3.1.3(2)). The applicant must demonstrate to ISC that the onboard test fully meets all of the requirements of a test-bed procedure as specified in chapter 5 of this Code. In no case is an allowance to be granted for possible deviations of measurements if an initial survey is carried out on board a ship without any valid precertification test. For engines undergoing an onboard certification test, in order to be issued with an EIAPP Certificate, the same procedures apply as if the engine had been pre-certified on a test bed, subject to the limitations given in paragraph 3.4.4.2.

3.4.4.2 This pre-certification survey procedure may be accepted for an Individual Engine or for an Engine Group represented by the Parent Engine only, but it is not to be accepted for an Engine Family certification.

3.4.5 The engines are to be type approved prior to the pre-certification survey, or for new types of engines, the survey may be carried out combined with the type approval.

3.4.6 NO_x reducing devices

3.4.6.1 Where a NOx-reducing device is to be included within the EIAPP certification, it must be recognized as a component of the engine, and its presence shall be recorded in the engine's Technical File. The applicable test procedure shall be performed and the combined engine/NOx-reducing device shall be approved and pre-certified by the ISC taking into account Appendix 14. However, the pre-certification in accordance with the procedure not involving the testing for the combined engine/NOx-reducing device on a test bed as given by Appendix 14 is subject to the limitations given in paragraph 3.4.4.2.

3.4.6.2 In those cases where a NO_x reducing device has been fitted due to failure to meet the required emission value at the pre-certification test, in order to receive an EIAPP Certificate for this assembly, the engine, including the reducing device, as installed, must be re-tested to show compliance with the applicable NO_x emission limit. However, in this case, the assembly may be re-tested in accordance with the Simplified Measurement method in accordance with 6.3. In no case are the allowances to be given in 6.3.11 be granted.

3.4.6.3 Where, in accordance with 3.4.6.2, the effectiveness of the NO_x reducing device is verified by use of the Simplified Measurement method, that test report is to be added as an adjunct to the pre-certification test report which demonstrated the failure of the engine alone to meet the required emission value. Both test reports are to be submitted to ISC, and test report data, as detailed in 3.4.9.1(5), covering both tests are to be included in the engine's Technical File.

3.4.6.4 The Simplified Measurement method used as part of the process to demonstrate compliance in accordance with 3.4.6.2 may only be accepted in respect of the engine and NO_x reducing device on which its effectiveness was demonstrated, and it is not to be accepted for Engine Family or Engine Group certification.

3.4.6.5 In both cases as given in 3.4.6.1 and 3.4.6.2, the NO_x reducing device is to be included on the EIAPP Certificate together with the emission value obtained with the device in operation and all other records as required by the Administration. The engine's Technical File is also to contain onboard NO_x verification procedures for the device to ensure it is operating correctly.

Note: The guidelines to be developed by IMO may also be taken for reference for survey of NO_x reducing device. Appendix 14 may be taken for reference for survey of SCR after-treatment device.

3.4.7 Where, due to changes of component design, it is necessary to establish a new Engine Family or Engine Group but there is no available Parent Engine the engine builder may apply to ISC to use the previously obtained Parent Engine test data modified at each specific mode of the applicable test cycle so as to allow for the resulting changes in NO_x emission values. In such cases, the engine used to determine the modification emission data is to correspond in accordance with the requirements of 4.3.4.1, 4.3.4.2 and 4.3.4.3 to the previously used Parent Engine. Where more than one component is to be changed the combined effect resulting from those changes is to be demonstrated by a single set of test results.

3.4.8 Test-bed test

3.4.8.1 The manufacturer of the engine and the testing organization are to carry out the test according to the approved test programme and chapter 5 of the Guidelines.

3.4.8.2 ISC is to appoint the competent surveyor to carry out on-site testing verification and inspection, including:

(1) to witness whether the process of the testing comply with the requirements of test programme and chapter 5 of the Guidelines;

(2) to check whether the components, parameters and adjustable range of the engine conform with the approved technical information;

(3) for parent engine of engine Family/Group, to verify the selected parent engine is representative of the engine Family/Group. Where necessary, the test of another engine may be added for verification. The surveyor may also require that the adjustable parameters be tested within any specification within its adjustable range to verify that the NO_x emission comply with the emission limit.

3.4.9 Test result and Technical File

3.4.9.1 After the completion of the on-site testing, the applicant is to establish the Technical File as a basis for the issue of EIAPP Certificate and Statement of Compliance and the surveys thereafter, including at least:

(1) identification of those components, settings and operating values of the engine which influences its NO_x emissions including any NO_x reducing device or system;

(2) identification of the full range of allowable adjustments or alternatives for the components of the engine;

(3) full record of the relevant engine’s performance, including the engine’s rated speed and rated power;

(4) a system of onboard NO_x verification procedures to verify compliance with the NO_x emission limits during onboard verification surveys in accordance with chapter 6;

(5) a copy of the relevant Parent Engine test data, as given in section 2 of appendix 9 of the Guidelines;

(6) if applicable, the designation and restrictions for an engine which is an engine within an Engine Family or Engine Group;

(7) specifications of those spare parts/components which, when used in the engine, according to those specifications, will result in continued compliance of the engine with the applicable NO_x emission limit.

3.4.9.2 Description of the Technical File

(1) For 3.4.9.1(1) to (3), it is to be verified based on the checked Technical File and the result of the modification after on-site verification.

(2) For 3.4.9.1(4), the onboard NO_x verification procedure is to be one of the following methods:

① Engine Parameter Check method in accordance with 6.2 to verify that an engine’s component, setting and operating values have not deviated from the specifications in the engine’s Technical File (the method normally used);

② Simplified Measurement method in accordance with 6.3 (generally after engine modification); or

③ Direct Measurement and Monitoring method in accordance with 6.4 (generally applicable to engines fitted with NO_x reducing devices).

(3) Any of the three onboard NO_x verification procedures (parameter check method, simplified measurement method, direct measurement and monitoring method) may be applied other than at an engine's initial onboard survey. If the method differs from the verification procedure method specified in the Technical File as originally approved, the procedures associated with the method applied are to be approved by ISC and to be either added as an amendment to the Technical File or appended as an alternative to the procedure given in the Technical File. Thereafter the shipowner may choose which of the methods approved in the Technical File is to be used to demonstrate compliance.

(4) For 3.4.9.1(7), specifications of parts/components with effective identification method are to be listed. Such method is to ensure the effective identification during onboard check, such as specifications, identification numbers.

3.4.10 Issue of the certificate

3.4.10.1 The applicant is to submit the Technical File to ISC for review and EIAPP Certificate or Statement of Compliance is to be issued after approval. After 1 July 2010, where the applicant is the Contracting Party and the requirements of 2008 NTC is met, the EIAPP Certificate is to be issued according to the format as specified in appendix 3. Where the applicant is not the Contracting Party and the requirements of 2008 NTC is met, the Statement of Compliance may be issued according to the format as specified in appendix 4.

3.4.10.2 Issue of certification by the Administration of the country in which the engine is built

(1) When an engine is manufactured outside the country of the Administration of the ship on which it will be installed, the Administration of the ship may request the Administration of the country in which the engine is manufactured to survey the engine. Upon satisfaction that the applicable requirements of chapter 2 are complied with pursuant to the Guidelines, the Administration of the country in which the engine is manufactured is to issue or authorize the issuance of the EIAPP Certificate.

(2) A copy of the certificate(s) and a copy of the survey report are to be transmitted as soon as possible to the requesting Administration.

(3) A certificate so issued is to contain a statement to the effect that it has been issued at the request of the Administration.

3.4.10.3 For pre-certification of engines within an Engine Family or Engine Group, an EIAPP Certificate is to be issued in accordance with requirements of chapter 4 to the Parent Engine(s) and to every Member Engine produced under this certification.

3.4.10.4 The EIAPP Certificate or Statement of Compliance is to be added into the Technical File together with the engine onboard the ship to accompany the engine throughout its life.

3.4.11 Guidance in respect of the pre-certification survey and certification of marine diesel engines is given in the relevant flowchart in appendix 5 of the Guidelines.

3.5 Procedures for onboard survey of an engine

3.5.1 After installation on board, it is to be determined to what extent an engine has been subjected to further adjustments and/or modifications which could affect the NO_x emission. Therefore, the engine, after installation on board, but prior to issuance of the IAPP Certificate, is to be inspected for modifications and be approved using the onboard NO_x verification procedures and one of the methods described in 3.1.3.

3.5.2 The shipbuilder or ship owner is to apply for the survey timely according to 3.1.2.2 to 3.1.2.4 and 3.3 of the Guidelines to avoid undue delay and the invalidation of the certificate.

3.5.3 Where any adjustment or modification of the engine exceeds the limit of Technical File, the application for the survey is to be made timely according to 3.3 to avoid the invalidation of the certificate. The following information are also to be submitted for the application:

(1) description of the adjustments to the engine which influencing NO_x emission; and/or

(2) description and technical information of the modification to the engine which influencing NO_x emission.

3.5.4 ISC is to review the submitted information to decide whether the information is to be supplemented or the further description is needed and whether to accept the information.

3.5.5 Onboard verification

(1) The Technical File of the engine is to be kept onboard the ship for further examination and survey at any time.

(2) The applicant is to make preparation well and assist in verification to avoid undue delay of the ship.

(3) The surveyor is to carry out the onboard verification according to the Onboard NO_x verification procedures put forward by the applicant and approved by ISC and the relevant requirements of chapter 6.

3.5.6 Where it is verified that the NOx emission of the engine comply with the emission limit and all the other applicable requirements of annex VI are met, the IAPP Certificate may be issued according to regulation 5 of annex VI.

3.5.7 Where the Engine Parameter Check method in accordance with 6.2 is used to verify compliance, if any adjustments or modifications are made to an engine after its pre-certification, a full record of such adjustments or modifications is to be recorded in the engine's Record Book of Engine Parameters.

3.5.8 If all of the engines installed on board are verified to remain within the parameters, components, and adjustable features recorded in the Technical File, the engines are to be accepted as performing within the applicable NO_x limit specified in chapter 2. In this case, provided all other applicable requirements of the Annex VI are complied with, an IAPP Certificate is then to be issued to the ship.

3.5.9 If any adjustment or modification is made which is outside the approved limits documented in the Technical File, the IAPP Certificate may be issued only if the overall NO_x emission performance is verified to be within the required limits by: onboard Simplified Measurement in accordance with 6.3; or, reference to the test-bed testing for the relevant Engine Group approval showing that the adjustments or modifications do not exceed the applicable NO_x emission limit. At surveys after the initial engine survey, the Direct Measurement and Monitoring method in accordance with 6.4, as approved by ISC, may alternatively be used.

3.5.10 Where a NO_x reducing device is installed and needed to comply with the NO_x limits, one of the options providing a ready means for verifying compliance with chapter 2 is the Direct Measurement and Monitoring method in accordance with 6.4. However, depending on the technical possibilities of the device used, subject to the approval of ISC, other relevant parameters could be monitored.

3.5.11 Where, for the purpose of achieving NO_x compliance, an additional substance is introduced, such as ammonia, urea, steam, water, fuel additives, etc., a means of monitoring the consumption of such substance is to be provided. The Technical File is to provide sufficient information to allow a ready means of demonstrating that the consumption of such additional substances is consistent with achieving compliance with the applicable NO_x limit.

3.5.12 All parts of the survey on board may be abbreviated or reduced to an engine which has been issued an EIAPP Certificate. However, the entire survey on board must be completed for at least one cylinder and/or one engine in an Engine Family or Engine Group, if applicable, and the abbreviation may be made only if all the other cylinders and/or engines are expected to perform in the same manner as the surveyed engine and/or cylinder. As an alternative to the examination of fitted components, ISC may conduct that part of the survey on spare parts carried on board provided they are representative of the components fitted.

3.5.13 As a general principle, onboard NO_x verification procedures are to enable a surveyor to easily determine if an engine has remained in compliance with the applicable requirements of chapter 2. At the same time, it is not to be so burdensome as to unduly delay the ship or to require in-depth knowledge of the characteristics of a particular engine or specialist measuring devices not available on board.

3.5.14 Guidance in respect of the survey and certification of marine diesel engines at initial, renewal, annual and intermediate surveys is given in the flowcharts in appendix 5 of the Guidelines.

3.6 Certification of an existing engine

3.6.1 Where an Existing Engine is to comply with 2.4 of the Guidelines, then the entity responsible for obtaining emissions certification is to apply to ISC for certification.

3.6.2 Where an application for Approved Method approval includes gaseous emission measurements and calculations, those are to be in accordance with chapter 5.

3.6.3 Emission and performance data obtained from one engine may be shown to apply to a range of engines.

3.6.4 The Approved Method for achieving compliance with regulation 2.4 is to include a copy of the Approved Method File which is required to accompany the engine throughout its life on board ship.

3.6.5 A description of the engine's onboard verification procedure is to be included in the Approved Method File.

3.6.6 After installation of the Approved Method, a survey is to be conducted in accordance with the Approved Method File. If this survey confirms compliance, ISC is to amend the ship's IAPP Certificate accordingly.

3.7 General requirements for certification

3.7.1 The procedures for determining NO_x emissions set out in the Guidelines are intended to be representative of the normal operation of the engine.

3.7.2 Defeat devices and irrational emission control strategies which may undermine emission characteristics of the engine under normal operation are not to be allowed during survey. The above mentioned situation is not to include the use of auxiliary control devices that are used to protect the engine and/or its ancillary equipment against operating conditions that could result in damage or failure or that are used to facilitate the starting of the engine.

Chapter 4 Engine Family and Engine Group Concepts

4.1 General requirements

4.1.1 To avoid certification testing of every engine for compliance with the NO_x emission limits, one of two approval concepts may be adopted, namely the Engine Family or the Engine Group concept.

4.1.2 The Engine Family concept may be applied to any series produced engines which, through their design are proven to have similar NO_x emission characteristics, are used as produced, and, during installation on board, require no adjustments or modifications which could adversely affect the NO_x emissions.

4.1.3 The Engine Group concept may be applied to a smaller series of engines produced for similar engine application and which require minor adjustments and modifications during installation or in service on board. These engines are normally large power engines for main propulsion.

4.1.4 Initially the engine manufacturer may, at its discretion, determine whether engines are to be covered by the Engine Family or Engine Group concept. In general, the type of application is to be based on whether the engines will be modified, and to what extent, after testing on a test bed.

4.2 Approval of Engine Family

4.2.1 The Engine Family concept provides the possibility of reducing the number of engines which must be submitted for approval testing, while providing safeguards that all engines within the Engine Family comply with the approval requirements.

4.2.2 In the engine family concept, engines with similar emission characteristics and design are represented by a parent engine for certification testing so as to be taken as a basis for the approval and certification of all engines within the family.

4.2.3 The Engine Family concept does allow minor adjustments to the engines through adjustable features. Marine diesel engines equipped with adjustable features must comply with all requirements for any adjustment within the physically available range. A feature is not considered adjustable if it is permanently sealed or otherwise not normally accessible.

4.2.4 On the basis of tests and engineering judgement, the manufacturer is to propose which engines belong to an Engine Family, which engine(s) produce the highest NO_x emissions, and which engine(s) is (are) to be selected for certification testing.

4.2.5 Before granting an Engine Family approval, ISC is to take the necessary measures to verify that adequate arrangements have been made to ensure effective control of the conformity of production. This may include, but is not limited to:

(1) the connection between the NO_x critical component part or identification numbers as proposed for the Engine Family and the drawing numbers (and revision status if applicable) defining those components;

(2) the means by which ISC will be able, at the time of a survey, to verify that the drawings used for the production of the NO_x critical components correspond to the drawings established as defining the Engine Family;

(3) drawing revision control arrangements. Where it is proposed by a manufacturer that revisions to the NO_x critical component drawings defining an Engine Family may be undertaken through the life of an engine, then the conformity of production scheme would need to demonstrate the procedures to be adopted to cover the cases where revisions will, or will not, affect NO_x emissions. These procedures are to cover drawing number allocation, effect on the identification markings on the NO_x critical components and the provision for providing the revised drawings to ISC responsible for the original Engine Family approval, where these revisions may affect the NO_x emissions the means to be adopted to assess or verify performance against the Parent Engine

performance are to be stated together with the subsequent actions to be taken regarding advising ISC and, where necessary, the declaration of a new Parent Engine prior to the introduction of those modifications into service;

(4) the implemented procedures that ensure any NO_x critical component spare parts supplied to a certified engine will be identified as given in the approved Technical File and hence will be produced in accordance with the drawings as defining the Engine Family; or

(5) equivalent arrangements as approved by ISC.

4.2.6 Guidance for the selection of an Engine Family

4.2.6.1 The Engine Family is to be defined by basic characteristics which must be common to all engines within the Engine Family. In some cases there may be interaction of parameters; these effects must also be taken into consideration to ensure that only engines with similar exhaust emission characteristics are included within an Engine Family, e.g., the number of cylinders may become a relevant parameter on some engines due to the charge air or fuel system used, but with other designs, exhaust emissions characteristics may be independent of the number of cylinders or configuration.

4.2.6.2 The engine manufacturer is responsible for selecting those engines from their different models of engines that are to be included in an Engine Family. The following basic characteristics, but not specifications, are to be common among all engines within an Engine Family. However, the characteristics are not limited to the following, other features which could be considered to affect NO_x exhaust emissions are also to be listed by the manufacturer of the engine:

(1) combustion cycle:
- 2-stroke cycle
- 4-stroke cycle

(2) cooling medium:
- air
- water
- oil

(3) individual cylinder displacement:
- to be within a total spread of 15%

(4) number of cylinders and cylinder configuration:
- applicable in certain cases only, e.g., gas engine, engine in combination with exhaust gas cleaning devices (where the fuel consumption is calculated on the basis of individual cylinder in the fuel supply system, other engines with less cylinders than parent engine may belong to the same Engine Family.)

(5) method of air aspiration:
- naturally aspirated
- pressure charged

(6) fuel type:
- distillate/residual fuel oil
- dual fuel
– gas fuel

(7) combustion chamber
- open chamber
- divided chamber

(8) valve and porting, configuration, size and number:
- cylinder head
- cylinder wall

(9) fuel system type:
- pump-line-injector
- in-line
- distributor
- single element
- unit injector

- gas valve

(10) miscellaneous features:

- exhaust gas re-circulation
- water/emulsion injection
- air injection
- charge cooling system
- exhaust after-treatment
- reduction catalyst
- oxidation catalyst
- thermal reactor
- particulates trap

(11) ignition methods:

- compression ignition
- ignition by pilot injection
- ignition by spark plug or other external ignition device.

4.2.6.3 Engines that are series produced and not intended to be modified may be covered by the Engine Family concept.

4.2.7 Guidance for selecting the Parent Engine of an Engine Family

4.2.7.1 The selection of the Parent Engine is to be based upon selecting an engine which incorporates engine features and characteristics which, from experience, are known to produce the highest NO_x emissions expressed in grams per kilowatt hour (g/kWh).

4.2.7.2 The Parent Engine is to have the highest emission value for the applicable test cycle.

4.2.7.3 The manufacturer of the engine is to clearly specify the selection procedure based on the above mentioned principles and approved by ISC.

4.2.7.4 If the range of engines within the Engine Family incorporate other variable features which could be considered to affect NO_x emissions, these features must also be identified and taken into account in the selection of the Parent Engine.

4.2.8 Determination and review of Engine Family and Parent Engine

4.2.8.1 On the basis of tests and engineering judgement, the manufacturer is to determine basic characteristics common to all engines within the Engine Family, and to propose which engines belong to an Engine Family, scale of adjustable features, the selection procedure for the Parent Engine, which engine(s) produce the highest NO_x emissions, and which engine(s) is to be selected for certification testing.

4.2.8.2 ISC is to review for approval of the submitted information mentioned above, where necessary, may require further information or on-site confirmation. And ISC may have the option of selecting a different engine, either for approval or production conformity testing, in order to have confidence that all engines within the Engine Family comply with the applicable NO_x emission limit.

4.2.9 Test of Engine Family

While testing the engine selected for certification testing, the surveyor may require that adjustable features be set to any specification within its adjustable range for certification or in-use testing to determine compliance with the requirements. For other test requirements, see specifications as detailed in chapter 5 for reference.

4.2.10 Certification of an Engine Family

4.2.10.1 The certification is to include a list, to be prepared and maintained by the engine manufacturer and approved by ISC, of all engines and their specifications accepted under the same Engine Family, the limits of their operating conditions and the details and limits of engine adjustments that may be permitted.

4.2.10.2 A pre-certificate, or EIAPP Certificate, is to be issued by ISC for a Member Engine of an

Engine Family in accordance with this Code which certifies that the Parent Engine meets the applicable NO_x limit.

4.2.10.3 When the Parent Engine of an Engine Family is tested and gaseous emissions measured under the most adverse conditions specified within the Guidelines and confirmed as complying with the applicable maximum allowable emission limits, the results of the test and NO_x measurement are to be recorded in the EIAPP Certificate issued for the particular Parent Engine and for all Member Engines of the Engine Family.

4.2.10.4 If two or more Administrations agree to accept each other’s EIAPP Certificates, then ISC is to issue the certificates according to the agreements between the Administrations.

4.2.10.5 If the Parent Engine of an Engine Family is to be certified in accordance with an alternative standard or a different test cycle than allowed by the Guidelines, the manufacturer must prove to ISC that the weighted average NO_x emissions for the appropriate test cycles fall within the relevant limit values under the Guidelines before ISC may issue an EIAPP Certificate.

4.3 Approval of Engine Group

4.3.1 Engine Group engines normally require adjustment or modification to suit the onboard operating conditions but these adjustments or modifications are not to result in NO_x emissions exceeding the applicable limits in chapter 2 of the Guidelines. The Engine Group concept also provides the possibility for a reduction in approval testing for modifications to engines in production or in service.

4.3.2 The application for the Engine Group concept, if requested by the engine manufacturer or another party, is to be considered for certification approval by ISC. If the engine owner, with or without technical support from the engine manufacturer, decides to perform modifications on a number of similar engines in the owner’s fleet, the owner may apply for an Engine Group certification. The Engine Group may be based on a Parent Engine which is a test engine on the test bench. Typical applications are similar modifications of similar engines in similar operational conditions. If a party other than the engine manufacturer applies for engine certification, the applicant for the engine certification takes on the responsibilities of the engine manufacturer as elsewhere given within the Guidelines.

4.3.3 Before granting an initial Engine Group approval for serially produced engines, ISC is to take the necessary measures to verify that adequate arrangements have been made to ensure effective control of the conformity of production. The requirements of 4.2.5 apply mutatis mutandis to this section. This requirement may not be necessary for Engine Groups MEPC established for the purpose of engine modification on board after an EIAPP Certificate has been issued.

4.3.4 Guidance for the selection of an Engine Group

4.3.4.1 The Engine Group may be defined by basic characteristics and specifications in addition to the parameters defined in 4.2.6 for an Engine Family.

4.3.4.2 The following parameters and specifications are to be common to engines within an Engine Group:

(1) bore and stroke dimensions;
(2) method and design features of pressure charging and exhaust gas system:
- constant pressure;
- pulsating system;
(3) method of charge air cooling system:
- with/without charge air cooler;
(4) design features of the combustion chamber that effect NO_x emission;
(5) design features of the fuel injection system, plunger and injection cam or gas valve which may profile basic characteristics that effect NO_x emission; and
(6) rated power at rated speed. The permitted ranges of engine power (kW/cylinder) and/or rated speed are to be declared by the manufacturer and approved by ISC.

4.3.4.3 Generally, if the criteria required by 4.3.4.2 are not common to all engines within a prospective Engine Group, then those engines may not be considered as an Engine Group. However, an Engine Group may be accepted if only one of those criteria is not common for all of the engines within a prospective Engine Group.

4.3.5 Guidance for allowable adjustment or modification within an Engine Group

Minor adjustments and modifications in accordance with the Engine Group concept are allowed after pre-certification or final test-bed measurement within an Engine Group, if:

(1) an inspection of emission-relevant engine parameters and/or provisions of the onboard NO_x verification procedures of the engine and/or data provided by the engine manufacturer confirm that the adjusted or modified engine complies with the applicable NO_x emission limit. The engine test-bed results in respect of NO_x emissions may be accepted as an option for verifying onboard adjustments or modifications to an engine within an Engine Group; or

(2) onboard measurement confirms that the adjusted or modified engine complies with the applicable NO_x emission limit.

4.3.6 Examples of adjustments and modifications within an Engine Group that may be permitted, but are not limited to those described below:

(1) For onboard conditions, adjustment of:
- injection or ignition timing for compensation of fuel property differences,
- injection or ignition timing for maximum cylinder pressure,
- fuel delivery differences between cylinders.

(2) For performance, modification of:
- turbocharger,
- injection pump components,
- plunger specification,
- delivery valve specification,
- injection nozzles,
- cam profiles,
- intake and/or exhaust valve,
- injection cam,
- combustion chamber,
– gas valve specification.

4.3.7 Guidance for the selection of the Parent Engine of an Engine Group

The selection of the Parent Engine is to be in accordance with the criteria in 4.2.7, as applicable. It is not always possible to select a Parent Engine from small-volume production engines in the same way as the mass-produced engines (Engine Family). The first engine ordered may be registered as the Parent Engine. Furthermore at the pre-certification test where a Parent Engine is not adjusted to the engine builder defined reference or maximum tolerance operating conditions (which may include, but not limited to, maximum combustion pressure, compression pressure, exhaust back pressure, charge air temperature) for the Engine Group, the measured NO_x emission values are to be corrected to the defined reference and maximum tolerance conditions on the basis of emission sensitivity tests on other representative engines. The resulting corrected average weighted NO_x emission value under reference conditions is to be stated in 1.9.6 of the Supplement to the EIAPP Certificate. In no case is the effect of the reference condition tolerances to result in an emission value which would exceed the applicable NO_x emission limit as required by chapter 2. The method used to select the Parent Engine to represent the Engine Group, the reference values and the applied tolerances are to be agreed to and approved by ISC.

4.3.8 The determination, review and certification of Engine Group and Parent Engine are to be carried out according to the applicable requirements in 4.2.8 and 4.2.10.

Chapter 5 Procedures for NO_x Emission Measurements on a Test Bed

5.1 General requirements

5.1.1 In principle, during emission tests, an engine is to be equipped with its auxiliaries in the same manner as it would be used on board. For many engine types within the scope of the Guidelines, the auxiliaries which may be fitted to the engine in service may not be known at the time of manufacture or certification. It is for this reason that the emissions are expressed on the basis of brake power as defined in 1.3.1(13). When it is not appropriate to test the engine under the conditions as defined in 1.3.1(13), e.g., if the engine and transmission form a single integral unit, the engine may only be tested with other auxiliaries fitted. In this case the dynamometer settings are to be determined in accordance with 5.3.3.2 and 5.8. The auxiliary losses are not to exceed 5% of the maximum observed power. Losses exceeding 5% are to be approved by ISC involved prior to the test.

5.1.2 This chapter specifies the measurement and calculation methods for gaseous exhaust emissions from engines under steady-state conditions, except as specially specified by individual regulations, necessary for determining the average weighted value for the NO_x exhaust gas emission.

5.1.3 Except as otherwise specified, all results of measurements, test data or calculations required by this chapter are to be recorded in the engine's test report in accordance with 5.9.

5.1.4 All volumes and volumetric flow rates are to be related to 273 K (0℃) and 101.3 kPa.

5.2 Applications

5.2.1 The chapter applies to the engine's pre-certification test-bed.

5.2.2 For engines which cannot be pre-certified on a test-bed as mentioned in 3.4.4, onboard test may be carried out with the approval of ISC and all the requirements for test-bed testing are to be met.

5.3 Test conditions

5.3.1 Test condition parameter f_a and test validity for Engine Family approval

(1) For naturally aspirated and mechanically pressure charged engines operating on liquid or dual fuel the parameter f_a is to be determined according to the following:

$$f_a = \left(\frac{99}{p_s}\right) \cdot \left(\frac{T_a}{298}\right)^{0.7} \quad (1)$$

(2) For turbocharged engines operating on liquid or dual fuel with or without cooling of the intake air the parameter f_a is to be determined according to the following:

$$f_a = \left(\frac{99}{p_s}\right)^{0.7} \cdot \left(\frac{T_a}{298}\right)^{1.5} \quad (2)$$

For engines to be tested with gas fuel only with or without cooling of the intake air, the parameter f_a is to be determined according to the following:

$$f_a = \left(\frac{99}{p_s}\right)^{1.2} \cdot \left(\frac{T_a}{298}\right)^{0.6} \quad (2a)$$

where: p_s— dry atmospheric pressure, kPa, which is determined according to the following:

$$p_s = p_b - 0.01\ p_a\ R_a \quad (3)$$

where: p_b— total barometric pressure, in kPa;

p_a—saturation vapour pressure of the intake air, kPa, according to formula (11);

R_a — relative humidity of intake air, in %;

T_a — the absolute temperature of intake air, in K.

(1) Where $0.93 \leq f_a \leq 1.07$, the test is recognized as valid.

5.3.2 Engines with charge air cooling

5.3.2.1 The temperature of the cooling medium and the charge air temperature are to be recorded.

5.3.2.2 All engines when equipped as intended for installation on board ships must be capable of operating within the applicable NO_x emission limit of chapter 2 of the Guidelines at an ambient seawater temperature of 25℃. This reference temperature is to be considered in accordance with the charge air cooling arrangement applicable to the individual installation as follows:

(1) Direct seawater cooling to engine charge air coolers. Compliance with the applicable NO_x limit is to be demonstrated with a charge air cooler coolant inlet temperature of 25℃.

(2) Intermediate freshwater cooling to engine charge air coolers. Compliance with the applicable NO_x limit is to be demonstrated with the charge air cooling system operating with the designed in service coolant inlet temperature regime corresponding to an ambient seawater temperature of 25℃.

Note: Demonstration of compliance at a Parent Engine test for a direct seawater cooled system, as given by (1) above, does not demonstrate compliance in accordance with the higher charge air temperature regime inherent with an intermediate freshwater cooling arrangement as required by this section.

(3) For those installations incorporating no seawater cooling, either direct or indirect, to the charge air coolers, e.g., radiator cooled freshwater systems, air/air charge air coolers, compliance with the applicable NO_x limit is to be demonstrated with the engine and charge air cooling systems operating as specified by the manufacturer with 25℃ air temperature.

5.3.2.3 Compliance with the applicable NO_x emission limit as defined by chapter 2 of the Guidelines is to be demonstrated either by testing or by calculation using the charge air reference temperatures (T_{SCRef}) specified and justified by the manufacturer, if applicable. Where the reference temperature conditions of the engine is not adjusted to that specified in 5.3.2.2, the NO_x emission is to be corrected according to formula (18) as defined in 5.7.2.5.

5.3.3 Power

5.3.3.1 The basis of specific emissions measurement is uncorrected brake power as defined in 1.3.1(13). The engine is to be submitted with auxiliaries needed for operating the engine (e.g., fan, water pump, etc.) during the test-bed testing. If it is impossible or inappropriate to install the auxiliaries on the test bench, the power absorbed by them is to be determined and subtracted from the measured engine power.

5.3.3.2 The fitted auxiliaries which are not necessary for the operation of the engine are to be removed from the test bed. For those cannot be removed, the power absorbed by them at the test speeds is to be determined in order to calculate the brake power P:

$$P=P_m+P_{aux} \tag{4}$$

where: P_m is the measured power of this mode;

P_{aux} is the total power absorbed by the unnecessary auxiliaries in the test-bed test of this mode.

5.3.4 Provision of the test engine

5.3.4.1 An engine air intake system or a test shop system is to be used presenting an air intake restriction within ±300 Pa of the maximum value specified by the manufacturer for a clean air cleaner at the speed of rated power and full-load. If the engine is equipped with an integral air inlet system, it is to be used for testing.

5.3.4.2 Engine exhaust system

(1) An engine exhaust system or a test shop system is to be used which presents an exhaust backpressure within ± 650 Pa of the maximum value specified by the manufacturer at the speed of rated power and full load. If the engine is equipped with an integral exhaust system, it is to be used for testing.

(2) The exhaust system is to conform to the requirements for exhaust gas sampling, as set out in 5.8.1.

(3) If the engine is equipped with an exhaust after-treatment device, the exhaust pipe is to have the same diameter as found in-use for at least 4 pipe diameters upstream to the inlet of the beginning of the expansion section containing the after-treatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust after-treatment device is to be the same as in the onboard configuration or within the distance specifications of the manufacturer. The exhaust backpressure or restriction is to follow the same criteria as above, and may be set with a valve.

(4) Where test-bed installation prevents adjustment to the exhaust gas backpressure as required, the effect on the NO_x emissions is to be demonstrated by the engine builder and, with the approval of ISC, the emission value duly corrected as necessary.

5.3.4.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer is to be used.

5.4 Test fuel oils

5.4.1 The characteristics of the fuel oil used for the test are to be determined and recorded. Where a reference fuel oil is used, the reference code or specifications and the analysis of the fuel oil are to be provided.

5.4.2 The selection of the fuel oil for the test depends on the purpose of the test. If a suitable reference fuel oil is not available, it is recommended to use a DM-grade marine fuel specified in ISO 8217:2005 at the discretion of ISC, with properties suitable for the engine type. In case a DM-grade fuel oil is not available, a RM-grade fuel oil according to ISO 8217:2005 is to be used. The fuel oil is to be analysed for its composition of all components necessary for a clear specification and determination of DM- or RM-grade. The nitrogen content is also to be determined. The fuel oil used during the Parent Engine test is to be sampled during the test.

5.4.3 The fuel oil temperature is to be in accordance with the manufacturer’s recommendations. The fuel oil temperature is to be measured at the inlet to the engine, or as specified by the manufacturer, and the temperature and location of measurement recorded.

5.4.4 The selection of gas fuel for testing depends on the aim of tests. In case where an appropriate standard gas fuel is not available, other gas fuels are to be used with the approval of ISC. A gas fuel sample is to be collected during the test of the parent engine. The gas fuel is to be analysed to give fuel composition and fuel specification.

5.4.5 Gas fuel temperature is to be measured and recorded together with the measurement point position.

5.4.6 Gas mode operation of dual fuel engines using liquid fuel as pilot or balance fuel is to be tested using maximum liquid-to-gas fuel ratio, such maximum ratio means for the different test cycle modes the maximum liquid-to-gas setting certified. The liquid fraction of the fuel is to comply with 5.4.1, 5.4.2 and 5.4.3.

5.5 Measurement equipment and data to be measured

5.5.1 The emission of gaseous components by the engine submitted for testing is to be measured by the methods described in appendix 7 of the Guidelines which describe the recommended analytical systems for the gaseous emissions.

5.5.2 Other systems or analysers may, subject to the approval of ISC, be accepted if they yield equivalent results to that of the equipment referenced in 5.5.1. In establishing equivalency it is to be demonstrated that the proposed alternative systems or analysers would, as qualified by using recognized national or international standards, yield equivalent results when used to measure marine diesel engine exhaust emission concentrations in terms of the requirements referenced in 5.5.1. For introduction of a new system the determination of equivalency is to be based upon the calculation of repeatability and reproducibility, as described in ISO 5725-1 and ISO 5725-2, or any other comparable recognized standard.

5.5.3 The accuracy requirements of flow, pressure, and temperature measuring equipment are to comply with 1.3.1 if appendix 8 of the Guidelines.

5.5.4 The water brake and instrumentation for torque and speed measurement are to comply with the procedure requirements for the engine’s test-bed testing. The accuracy of the measuring equipment is to be such that the maximum permissible deviations given in 1.3.1 of appendix 8 of the Guidelines are not exceeded.

5.6 Determination of exhaust gas flow

5.6.1 Direct measurement method

5.6.1.1 This method involves the direct measurement of the exhaust flow by flow nozzle or equivalent metering system and is to be in accordance with a recognized international standard.

5.6.1.2 The requirements for the installation and measurement conditions of flow-meters is quite strict in direct gaseous flow measurement and precautions are to be taken as far as possible to avoid big measurement error.

Note: Direct gaseous flow measurement is a difficult task and it is not recommended in general.

5.6.2 Air and fuel measurement method

5.6.2.1 Air flow-meters and fuel flowmeters with an accuracy defined in 1.3.1 of appendix 8 of the Guidelines are to be used.

5.6.2.2 The exhaust flow is to be calculated according to the following formulae after the intake air flow and fuel consumption are measured.

$$q_{\mathrm{mew}} = q_{\mathrm{maw}} + q_{\mathrm{mf}} \tag{5}$$

5.6.2.3 Specially designed measurement devices such as air flow-meters matched with each type of engine are to be provided using such mehod.

5.6.2.4 It is quite difficult to use this method for measuring intake air flow of large and part of medium sized engines due to their structures.

5.6.3 Carbon balance method

This involves exhaust mass flow rate calculation from fuel consumption, fuel composition and exhaust gas concentrations using the carbon balance method, as specified in appendix 10 of the Guidelines.

5.7 Calculation of the gaseous emissions

5.7.1 Dry/wet correction of exhaust gas concentrations

5.7.1.1 If the measured concentration is the dry concentration c_w, it is to be converted to a wet concentration c_{d} according to either of the following formulae:

$$c_{\mathrm{w}} = k_{\mathrm{w}} \cdot c_{\mathrm{d}} \tag{6}$$

5.7.1.2 Dry/wet correction factor for the raw exhaust gas k_{wr}

(1) Complete combustion where exhaust gas flow is to be determined in accordance with direct measurement method in 5.6.1 or air and fuel measurement method in 5.6.2 formula (7) or (8) is to be used:

$$k_{wr1} = \left(1 - \frac{1.2442 \cdot H_a + 111.19 \cdot w_{ALF} \cdot \frac{q_{mf}}{q_{mad}}}{773.4 + 1.2442 \cdot H_a + \frac{q_{mf}}{q_{mad}} \cdot f_{fw} \cdot 1000}\right) \cdot 1.008 \qquad (7)$$

or

$$k_{wr1} = \left(1 - \frac{1.2442 \cdot H_a + 111.19 \cdot w_{ALF} \cdot \frac{q_{mf}}{q_{mad}}}{773.4 + 1.2442 \cdot H_a + \frac{q_{mf}}{q_{mad}} \cdot f_{fw} \cdot 1000}\right) / (1 - \frac{p_r}{p_b}) \qquad (8)$$

with $f_{fw} = 0.055594 \cdot w_{ALF} + 0.0080021 \cdot w_{DEL} + 0.0070046 \cdot w_{EPS}$ (9)

H_a is the absolute humidity of intake air, in g water per kg dry air

$$H_a = 6.22 \cdot p_a \cdot R_a / (p_b - 0.01 \cdot R_a \cdot p_a) \qquad (10)$$

Note: Ha may be derived from relative humidity measurement, dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

where: p_a = saturation vapour pressure of the intake air, in kPa, according to formula (11):

$$p_a = (4.856884 + 0.2660089 \cdot t_a + 0.01688919 \cdot t_a^2 - 7.477123 \cdot 10^{-5} \cdot t_a^3 + 8.10525 \cdot 10^{-6} \cdot t_a^4 - 3.115221 \cdot 10^{-8} \cdot t_a^5) \ (101.32/760) \qquad (11)$$

t_a = temperature of the intake air, ℃ ; $t_a = T_a - 273.15$

pb = total barometric pressure, in kPa

pr = water vapour pressure after cooling bath of the analysis system, in kPa

pr = 0.76 kPa for cooling bath temperature 3℃.

(2) Incomplete combustion, CO more than 100 ppm or HC more than 100 ppmC at one or more mode points, where exhaust gas flow is determined in accordance with direct measurement method 5.6.1, air and fuel measurement method 5.6.2 and in all cases where the carbon-balance method 5.6.3 is used equation (12) is to be used:

$$k_{wr2} = \frac{1}{1 + \alpha \cdot 0.005 \cdot (c_{CO_2d} + c_{COd}) - 0.01 \cdot c_{H_2d} + k_{w2} - \frac{p_r}{p_b}} \qquad (12)$$

with

$$\alpha = 11.9164 \cdot \frac{w_{ALF}}{w_{BET}}; \qquad (13)$$

$$c_{H2d} = \frac{0.5 \cdot \alpha \cdot c_{COd} \cdot (c_{COd} + c_{CO_2d})}{c_{COd} + 3 \cdot c_{CO_2d}}; \qquad (14)$$

$$k_{w2} = \frac{1.608 \cdot H_a}{1000 + (1.608 \cdot H_a)} \qquad (15)$$

Note: The unit for the CO and CO2 concentrations in (12) and (14) is %.

(3) The calculation is to be in accordance with paragraphs 5.7.1.1 to 5.7.1.2. However, q_{mf}, W_{ALF},

W_{BET}, W_{DEL}, W_{EPS}, f_{fw} values are to be calculated in accordance with the following table:

Factors in the formula (7)(8)(9)		Formula for factors
q_{mf}	=	$q_{mf\_G} + q_{mf\_L}$
W_{ALF}	=	$\frac{q_{mf\_G} \times w_{ALF\_G} + q_{mf\_L} \times w_{ALF\_L}}{q_{mf\_G} + q_{mf\_L}}$
W_{BET}	=	$\frac{q_{mf\_G} \times w_{BET\_G} + q_{mf\_L} \times w_{BET\_L}}{q_{mf\_G} + q_{mf\_L}}$
W_{DEL}	=	$\frac{q_{mf\_G} \times w_{DEL\_G} + q_{mf\_L} \times w_{DEL\_L}}{q_{mf\_G} + q_{mf\_L}}$
W_{EPS}	=	$\frac{q_{mf\_G} \times w_{EPS\_G} + q_{mf\_L} \times w_{EPS\_L}}{q_{mf\_G} + q_{mf\_L}}$

5.7.1.3 Dry/wet correction factor for the intake air k_{wa}

$$k_{wa} = 1 - k_{w2} \quad (16)$$

5.7.2 NO_x correction for humidity and temperature

5.7.2.1 Where the measured ambient air conditions (temperature and humidity) is not the standard one, the NO_x concentration is to be corrected for ambient air humidity multiplied by correction factor k_{hd}.

5.7.2.2 The standard ambient air conditions relating to NO_x temperature and humidity correction calculation means: the value for humidity at the reference temperature of 25℃ is to be 10.71 g/kg. Other reference values for humidity instead of 10.71 g/kg are not to be used.

5.7.2.3 Water or steam injected into the charge air (air humidification) is considered an emission control device and is therefore not to be taken into account for humidity correction. Water that condensates in the charge cooler will change the humidity of the charge air and therefore is to be taken into account for humidity correction.

5.7.2.4 For diesel engines in general, the following formula for calculating K_{hd} is to be used:

$$k_{hd} = \frac{1}{1 - 0.0182 \cdot (H_a - 10.71) + 0.0045 \cdot (T_a - 298)} \quad (17)$$

where: T_a = is the temperature of the air at the inlet to the air filter, in K;

H_a = is the humidity of the intake air at the inlet to the air filter in g water per kg dry air.

5.7.2.5 For compression ignition engines with intermediate air cooler the following alternative equation is to be used for calculation of k_{hd}:

$$k_{hd} = \frac{1}{1 - 0.012 \cdot (H_a - 10.71) - 0.00275 \cdot (T_a - 298) + 0.00285 \cdot (T_{SC} - T_{SCRef})} \quad (18)$$

where: T_{SC} is the temperature of the charge air, in K;

T_{SCRef} is the temperature of the charge air at each mode point corresponding to a seawater temperature of 25℃, in K; T_{SCRef} is to be specified by the manufacturer.

To take the humidity in the charge air into account, the following consideration is added:

H_{SC} = humidity of the charge air, in g water per kg dry air in which:

H_{SC} = 6.22 P_{SC} 100/(P_C-P_{SC}) (19)

where: P_{SC} = saturation vapour pressure of the charge air, in kPa

P_C = charge air pressure, in kPa

However if $H_a \geq H_{SC}$, then H_{SC} is to be used in place of H_a in formula (19) or (19a)."

5.7.2.6 For engines to be tested with gas fuel only:

$$k_{hd} = 0.6272 + 44.030 \times 10^{-3} \times H_a - 0.862 \times 10^{-3} \times H_a^2 \quad (19a)$$

where:

H_a is the humidity of the intake air at the inlet to the air filter, in g water per kg dry air.

5.7.3 Calculation of the emission mass flow rates

5.7.3.1 The emission mass flow rate of the respective component in the raw exhaust gas for each mode is to be calculated in accordance with the following formulae from the measured concentration as obtained in accordance with 5.9.1, the applicable u_{gas} value from Table 5.7.3.2 and the exhaust gas mass flow rate in accordance with 5.6.

$$q_{mgas} = u_{gas} \cdot c_{gas} \cdot q_{mew} \cdot k_{hd} \text{ (for } NO_x) \quad (20)$$

$$q_{mgas} = u_{gas} \cdot c_{gas} \cdot q_{mew} \text{ (for other gases)} \quad (21)$$

where: q_{mgas} = emission mass flow rate of individual gas, in g/h;

u_{gas} = ratio between density of exhaust component and density of exhaust gas, in 10^3, see Table 5.7.3.2;

c_{gas} = concentration of the respective component in the raw exhaust gas, in ppm, wet; The wet concentration is to be determined according to 5.7.1 if not already measured on a wet basis.

q_{mew} = exhaust mass flow, in kg/h, wet;

k_{hd} = NO_x humidity correction factor, according to 5.7.2.

Note: In the case of CO_2 and O_2 measurement, the concentration will normally be reported in terms of %. With regard to the application of formula (21), these concentrations will need to be expressed in ppm. 1.0 % = 10000 ppm.

5.7.3.2 Coefficient u_{gas} and fuel specific parameters for raw exhaust gas

Coefficient u_{gas} and fuel specific parameters for raw exhaust gas **Table 5.7.3.2**

Gas		NO_x	CO	HC	CO_2	O_2
ρ_{gas} kg/m^3		2.053	1.250	a)	1.9636	1.4277
	ρ_e c) kg/m^3	Coefficient u_{gas} d)				
Liquid fuel b)	1.2943	0.001586	0.000966	0.000479	0.001517	0.001103
Rapeseed Methyl Ester	1.2950	0.001585	0.000965	0.000536	0.001516	0.001102
Methanol	1.2610	0.001628	0.000991	0.001133	0.001557	0.001132
Ethanol	1.2757	0.001609	0.000980	0.000805	0.001539	0.001119
Natural gas	1.2661	0.001621	0.000987	0.000558	0.001551	0.001128
Propane	1.2805	0.001603	0.000976	0.000512	0.001533	0.001115
Butane	1.2832	0.001600	0.000974	0.000505	0.001530	0.001113

a) Depending on fuel.
b) Petroleum derived.
c) p_e is the nominal density of the exhaust gas.
d) At λ= 2, wet air, 273 K, 101.3 kPa.
Values for u given in table are based on ideal gas properties. In multiple fuel type operation, the u_{gas} value used shall be determined from the values applicable to those fuels in the table set out above proportioned in accordance with the fuel ratio used.

5.7.4 Calculation of brake specific mass emission:

5.7.4.1 The brake specific mass emission of the gaseous components of the exhaust gases is to be determined by the following formula:

$$gas_x = \frac{\sum_{i=1}^{i=n} q_{\mathrm{mgas},\,i} \cdot W_{\mathrm{F},\,i}}{\sum_{i=1}^{i=n} P_i \cdot W_{\mathrm{F},\,i}}, \text{ g/kWh} \qquad (22)$$

where: $P_i = P_{\mathrm{m},\,i} + P_{\mathrm{aux},\,i}$;

$W_{\mathrm{F},\,i}$ is the weighting factor.

5.7.4.2 The weighting factors and the number of modes (*n*) used in the above calculation are to be according to the provisions of 2.6.

5.7.4.3 The NO_x brake specific mass emission (g/kWh) of the tested engine as determined by formula (22) is then to be compared to the applicable NO_x emission limit given in chapter 2 of the Guidelines to determine if the engine is in compliance.

5.8 NO_x emission measurements on a test bed

5.8.1 Sampling requirements

(1) The sampling probes for the gaseous emissions are to be fitted at least 10 pipe diameters after the outlet of the engine, turbocharger, or last after-treatment device, whichever is furthest downstream, but also at least 0.5 m or 3 pipe diameters upstream of the exit of the exhaust gas system, whichever is greater. The sample probe is to be placed sufficiently close to the engine as possible as to ensure that the exhaust gas temperature at the sample probe is to be at least 70℃ and is to be at least 190℃ at the HC sample probe. For a short exhaust system that does not have a location that meets both of these specifications, an alternative sample probe location is to be subject to approval by ISC.

(2) In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe is to be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In the case of a multi-cylinder engine having distinct groups of manifolds, such as in a "V" engine configuration, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. Alternatively, it would also be permissible to acquire a sample from a single group to represent the average exhaust emission provided that it can be justified to ISC that the emissions from other groups are identical. For exhaust emission calculation, the total exhaust mass flow is to be used.

(3) The inlet of the probe is to be located as to avoid ingestion of water which is injected into the exhaust system for the purpose of cooling, tuning or noise reduction.

(4) The probe is to be properly fixed and is to be a stainless steel, straight, closed-end probe. There are to be a minimum of three holes in three different radial planes sized to sample approximately the same flow with the angle of 120°. The probe is to extend across at least 80% of the diameter of the exhaust pipe.

5.8.2 Preparation before the test

(1) The installation and connection of the equipment and measuring gauges are to be re-checked and confirmed reliable.

(2) The measuring equipment, instruments and gauges used for test are to be in compliance with 5.5 of the Guidelines.

(3) To confirm that the calibration of the scale and quench and interference checks have been carried out by the manufacturer of the instrument or have been checked during last maintenance.

(4) To check by means of the method for leakage test as specified in 4 of appendix 8 of the Guidelines as to ensure no leakage in the measuring system.

(5) A strip chart recorder or an equivalent data acquisition system connecting with the analyser is to be installed in order to check the history of the measured data.

(6) The analyser is to be put in an appropriate position with sufficient space and no obvious fluctuation in temperature, no vibration and to be as close to the exhaust pipe as possible. The sampling line between the probe and the analyser is not to be too long.

5.8.3 Commencement of the test

(1) The probe is to be fitted and all components connected (analyser, heated sampling line, heated sampling pump, strip chart recorder and other measuring instruments), and the two-hour warming-up is to be carried out for the measuring system or the recommendation of the manufacturer of the instrument is to be followed.

(2) The calibration of the instruments is to be carried out according to appendix 8 of the Guidelines or the specification of the manufacturer of the instrument. Where various measuring ranges are required for the measurement of exhaust gas concentrations, each used measuring range is to be calibrated.

(3) The engine is to be started for warming-up so that the operating parameters such as cooling water temperature, lubricating oil temperature, lubricating oil pressure are to reach the range specified by the manufacturer.

(4) Continuous tests are to be carried out according to the test cycles as defined in 2.6 and the measurement is to be carried out at each mode point after the engine is stabilized, the specified speed at each measurement point is to be held within ± 1% of the rated speed or ± 3 rpm whichever is greater except for low idle which is to be within the tolerances declared by the manufacturer. The specified torque is to be held so that the average over the period during which the measurements are being taken is within ± 2% of the rated torque at the engine's rated speed.

(5) When stabilized for at least 5 min, the output of the analysers is to be recorded on a strip chart recorder or a data acquisition system. The recording period is not to be less than 10 min when analysing exhaust gas or not less than 3 min for each zero and span response check. For data acquisition systems, a minimum sampling frequency of 3 per minute is to be used. Measured concentrations of CO, HC and NO_x are to be recorded in terms of, or equivalent to, ppm to at least the nearest whole number. Measured concentrations of CO_2 and O_2 are to be recorded in terms of, or equivalent to, % to not less than two decimal places.

(6) All the parameters such as speed, power, torque, temperature, pressure, humidity and fuel consumption are to be recorded during measurement.

(7) After the emission test, the zero and span responses of the analysers is to be re-checked using a zero gas and the same span gas as used prior to the measurements. The test is to be considered acceptable if the difference between the two responses results is less than 2% of the initial span gas concentration, or it is to be re-tested.

(8) Zero and span drift correction is not to be applied to the analyser responses recorded in accordance with 5.8.3(5).

5.9 Test report

5.9.1 After completion of the test, for the evaluation and calculation of the gaseous emissions, the data recorded for at least the last 60 s of each mode is to be averaged, and the concentrations of CO, CO_2, HC, NO_x, and O_2 during each mode are to be determined from the averaged recorded data and the corresponding zero and span check data. The averaged results are to be given in terms of % to not less than two decimal places for CO_2 and O_2 species and in terms of ppm to at least the nearest whole number for CO, HC and NO_x species. The final results for the test report are to be determined by following the steps in 5.6 to 5.7.

5.9.2 For every engine tested for pre-certification or for initial certification on board without pre-certification, the engine manufacturer is to prepare a test report which is to contain the necessary data to fully define the engine performance and enable calculation of the gaseous emissions including the data as set out in section 1 of appendix 9 of the Guidelines. The original of the test report is to be maintained on file with the engine manufacturer and a certified true copy is to be maintained on file by ISC.

5.9.3 See appendix 9 for the sample of the test report.

Chapter 6 Procedures for Demonstrating Compliance with NO_x Emission Limits on Board

6.1 General requirements

6.1.1 Onboard verification method

After installation of a pre-certificated engine on board a ship, every marine diesel engine is to have an onboard verification survey conducted as specified in 3.1.2.2 to 3.1.2.4 to verify that the engine continues to comply with the applicable NO_x emission limit contained in chapter 2. Such verification of compliance is to be determined by using one of the following methods:

(1) Engine Parameter Check method in accordance with 6.2 to verify that an engine's component, settings and operating values have not deviated from the specifications in the engine's Technical File;

(2) Simplified Measurement method in accordance with 6.3; or

(3) Direct Measurement and Monitoring method in accordance with 6.4.

6.2 Engine Parameter Check method

6.2.1 General requirements

6.2.1.1 Engines that meet the following conditions are to be eligible for an Engine Parameter Check method:

(1) engines that have received a pre-certificate (EIAPP Certificate) on the test bed and those that received a certificate (EIAPP Certificate) following an initial certification survey in accordance with 3.4.4; and

(2) engines that have undergone modifications or adjustments to the designated engine components and adjustable features since they were last surveyed.

6.2.1.2 When a marine diesel engine is designed to run within the applicable NO_x emission limit, it is most likely that within the marine life of the engine, the NO_x emission limit may be adhered to. The applicable NO_x emission limit may, however, be contravened by adjustments or modification to the engine. Therefore, an Engine Parameter Check method is to be used to verify whether the engine is still within the applicable NO_x emission limit.

6.2.1.3 Engine component checks, including checks of settings and an engine's operating values, are intended to provide an easy means of deducing the emissions performance of the engine for the purpose of verification that an engine with no, or minor, adjustments or modifications complies with the applicable NO_x emission limit. Where the measurement of some operating values is required, the calibration of the equipment used for those measurements is to be in accordance with the requirements of appendix 8 of this Code.

6.2.1.4 The purpose of such checks is to provide a ready means of determining that an engine is correctly adjusted in accordance with the manufacturer's specification and remains in a condition of adjustment consistent with the initial certification as being in compliance with the emission requirements in chapter 2.

6.2.1.5 If an electronic engine management system is employed, this is to be evaluated against the original settings to ensure that appropriate parameters are operating within "as-built" limits.

6.2.1.6 For an engine not equipped with a NO_x reducing device, it is not always necessary to measure the NO_x emissions to know that an engine, not equipped with an after-treatment device, is likely to comply with the applicable NO_x emission limit. It may be sufficient to know that the present state of the engine corresponds to the specified components, calibration or parameter adjustment state at the time of initial certification. If the results of an Engine Parameter Check method indicate the likelihood that the engine complies with the applicable NO_x emission limit, the engine may be recertified without direct NO_x measurement.

6.2.1.7 For an engine equipped with a NO_x reducing device, it will be necessary to check the operation of the device as part of the Engine Parameter Check method.

6.2.2 Documentation for an Engine Parameter Check method

6.2.2.1 Every marine diesel engine is to have a Technical File as required in 3.4.9 which identifies the engine's components, settings or operating values which influence exhaust emissions and must be checked to ensure compliance.

6.2.2.2 An engine's Technical File is to contain all applicable information, relevant to the NOx emission performance of the engine, on the designated engines components, adjustable features and parameters at the time of the engine's pre-certification or onboard certification, whichever occurred first.

6.2.2.3 Dependent on the specific design of the particular engine, different onboard NOx influencing modifications and adjustments are possible and usual. These include the engine parameters as follows:

— injection or ignition timing,

— injection nozzle,

— injection pump,

— fuel cam,

— injection pressure for common rail systems,

— combustion chamber,

— compression ratio,

— turbocharger type and build,

— charge air cooler, charge air pre-heater,

— valve timing,

— NO_x abatement equipment "water injection",

— NO_x abatement equipment "emulsified fuel" (fuel water emulsion),

— NO_x abatement equipment "exhaust gas recirculation",

— NO_x abatement equipment "selective catalytic reduction",

— other parameter(s) specified by ISC, or

— gas valve.

6.2.2.4 The actual Technical File of an engine may, based on the recommendations of the applicant for engine certification and the approval of ISC, include less components and/or parameters than discussed in section 6.2.2.3 depending on the particular engine and the specific design.

6.2.2.5 For some parameters, different survey possibilities exist. As approved by ISC, the shipowner, supported by the applicant for engine certification, may choose what method is applicable. Any one of, or a combination of, the methods listed in the check list for the Engine Parameter Check method given in appendix 11 of the Guidelines may be sufficient to show compliance.

6.2.2.6 Technical documentation in respect of engine component modification for inclusion in an engine's Technical File is to include details of that modification and its influence on NOx emissions, and it is to be supplied at the time when the modification is carried out. Test-bed data obtained from a later engine, which is within the applicable range of the Engine Group concept, may be accepted.

6.2.2.7 The following documentation in relation to the onboard NOx verification procedures are to be maintained on board:

(1) a Record Book or electronic record book[1] of Engine Parameters for recording all changes, including like for like replacements, and adjustments within the approved ranges made relative to an engine's components and settings;

(2) an engine parameter list of an engine's designated components and settings and/or the documentation of an engine's load-dependent operating values submitted by an applicant for engine certification and approved by ISC; and

(3) technical documentation of an engine component modification when such a modification is made to any of the engine's designated engine components.

6.2.2.8 Descriptions of any changes affecting the designated engine parameters, including adjustments, parts replacements and modifications to engine parts, are to be recorded chronologically in the Record Book of Engine Parameters. These descriptions are to be supplemented with any other applicable data used for the assessment of the engine's NOx emissions.

6.2.3 Procedures for an Engine Parameter Check method

6.2.3.1 An Engine Parameter Check method is to be carried out using the two procedures as follows:

(1) a documentation inspection of engine parameter(s) is to be carried out in addition to other inspections and include inspection of the Record Book of Engine Parameters and verification that engine parameters are within the allowable range specified in the engine's Technical File; and

(2) an actual inspection of engine components and adjustable features is to be carried out as necessary. It is then to be verified, also referring to the results of the documentation inspection, that the engine's adjustable features are within the allowable range specified in the engine's Technical File.

6.2.3.2 The surveyor is to have the option of checking one or all of the identified components, settings or operating values to ensure that the engine with no, or minor, adjustments or modifications complies with the applicable NOx emission limit and that only components of the approved specification, as given by 3.4.9.1(7), are being used. Where adjustments and/or modifications in a specification are referenced in the Technical File, they must fall within the range recommended by the applicant for engine certification and approved by ISC.

6.3 Simplified Measurement method

6.3.1 General requirements

6.3.1.1 The following simplified test and measurement procedure specified in this section are to be applied only for onboard confirmation tests and renewal, annual and intermediate surveys when required. Every first engine testing on a test bed is to be carried out in accordance with the procedure specified in chapter 5. Corrections for ambient air temperature and humidity in accordance with 5.7.2 are essential as ships are sailing in cold/hot and dry/humid climates, which may cause a difference in NO_x emissions.

6.3.1.2 To gain meaningful results for onboard confirmation tests and onboard renewal, annual and intermediate surveys, as an absolute minimum, the gaseous emission concentrations of NO_x and CO_2 are to be measured in accordance with the appropriate test cycle. The weighting factors (W_F) and the number of modes (n) used in the calculation are to be in accordance with 2.6.

6.3.1.3 The engine torque and engine speed are to be measured but, to simplify the procedure, the permissible deviations of instruments (see 6.3.7) for measurement of engine-related parameters for onboard verification purposes is different than from those permissible deviations allowed under the test-bed testing method. If it is difficult to measure the torque directly, the brake power may be estimated by any other means recommended by the applicant for engine certification and approved by ISC.

[1]Refer to the *Guidelines for the use of electronic record books under MARPOL*, adopted by resolution MEPC.312(74).

6.3.1.4 In practical cases, it is often impossible to measure the fuel oil consumption once an engine has been installed on board a ship. To simplify the procedure on board, the results of the measurement of the fuel oil consumption from an engine's pre-certification test-bed testing may be accepted. In such cases, especially concerning residual fuel oil operation (RM-grade fuel oil according to ISO 8217:2005) and gas fuel operation, an estimation with a corresponding estimated error is to be made. Since the fuel oil flow rate used in the calculation (q_{mf}) must relate to the fuel oil composition determined in respect of the fuel sample drawn during the test, the measurement of q_{mf} from the test-bed testing is to be corrected for any difference in net calorific values between the test bed and test fuel oils and gases. The consequences of such an error on the final emissions are to be calculated and reported with the results of the emission measurement.

6.3.1.5 Except as otherwise specified, all results of measurements, test data or calculations required by this chapter are to be recorded in the engine's test report in accordance with 5.9.

6.3.2 Engine parameters to be measured and recorded

Table 6.3.2 lists the engine parameters that are to be measured and recorded during onboard verification procedures.

Engine parameters to be measured and recorded **Table 6.3.2**

Symbol	Parameter	Dimension
$q_{mf,i}$	Fuel oil flow (at the i^{th} mode during the cycle)	kg/h
H_a	Absolute humidity (mass of engine intake air water content related to mass of dry air)	g/kg
$n_{d,i}$	Engine speed (at the i^{th} mode during the cycle)	rpm
$n_{turb,i}$	Turbocharger speed (if applicable) (at the i^{th} mode during the cycle)	rpm
p_b	Total barometric pressure (in ISO 3046-1, 1995: $p_x = P_x$ = site ambient total pressure)	kPa
$p_{C,i}$	Charge air pressure after the charge air cooler (at the i^{th} mode during the cycle)	kPa
P_i	Brake power (at the i^{th} mode during the cycle)	kW
s_i	Fuel rack position (of each cylinder, if applicable) (at the i^{th} mode during the cycle)	
T_a	Intake air temperature at air inlet (in ISO 3046-1, 1995: $T_x = TT_x$ = site ambient thermodynamic air temperature)	K
$T_{SC,i}$	Charge air temperature after the charge air cooler (if applicable) (at the i^{th} mode during the cycle)	K
T_{caclin}	Charge air cooler, coolant inlet temperature	℃
$T_{caclout}$	Charge air cooler, coolant outlet temperature	℃
$T_{Exh,i}$	Exhaust gas temperature at the sampling point (at the i^{th} mode during the cycle)	℃
$T_{Fuel\ L}$	Fuel oil temperature before the engine	℃
T_{Sea}	Seawater temperature	℃
T_{Fuel_G}	Gas fuel temperature before the engine	℃

* Only for engines to be tested with gas fuel.

6.3.3 Brake power

The point regarding the ability to obtain the required data during onboard NO_x testing is particularly relevant to brake power. An engine, as may be presented on board, could in many applications, be arranged such that the measurements of torque (as obtained from a specially installed strain gauge) may not be possible due to the absence of a clear shaft and engines may also be coupled to pumps, hydraulic units, compressors, etc. The brake power of such engines may be determined by the following methods: For generators this is not to pose a problem to use voltage and amperage measurements together with a manufacturer's declared generator efficiency. For propeller law governed equipment, a declared speed power curve may be applied together with ensured capability to measure engine speed, either from the free end or by ratio of, for example, the camshaft speed.

6.3.4 Test fuel oils

6.3.4.1 Generally all emission measurements with liquid fuel are to be carried out with the engine running on marine diesel fuel oil of an ISO 8217:2005, DM-grade. Generally all emission measurements with gas fuel are to be carried out with the engine running on gas fuel equivalent to ISO

8178-5:2008.

6.3.4.2 To avoid an unacceptable burden to the shipowner, the measurements for confirmation tests or re-surveys may, based on the recommendation of the applicant for engine certification and the approval of ISC, be allowed with an engine running on residual fuel oil of an ISO 8217:2005, RM-grade. In such a case the fuel bound nitrogen and the ignition quality of the fuel oil may have an influence on the NO_x emissions of the engine.

6.3.4.3 In case of a dual fuel or gas-fuelled engine, the gas fuel used is to be the gas fuel available on board.

6.3.5 Sampling for gaseous emissions

6.3.5.1 The general requirements described in 5.8.1 are also to be applied for onboard measurements.

6.3.5.2 The installation on board of all engines is to be such that these tests may be performed safely and with minimal interference to the engine. Adequate arrangements for the sampling of the exhaust gas and the ability to obtain the required data are to be provided on board a ship. The uptakes of all engines are to be fitted with an accessible standard sampling point. An example of a sample point connecting flange is given in section 5 of appendix 12 of the Guidelines.

6.3.6 Measurement equipment and data to be measured

The emission of gaseous pollutants is to be measured by the methods described in chapter 5.

6.3.7 Permissible deviation of instruments

Tables 3 and 4 contained in section 1.3 of appendix 8 of the Guidelines list the permissible deviation of instruments to be used in the measurement of engine-related parameters and other essential parameters during onboard verification procedures.

6.3.8 Determination of the gaseous components

The analytical measuring equipment and the methods described in chapter 5 are to be applied.

6.3.9 Test cycles

6.3.9.1 Test cycles used on board are to conform to the applicable test cycles specified in 2.6.

6.3.9.2 Engine operation on board under a test cycle specified in 2.6 may not always be possible, but the test procedure is to, based on the recommendation of the engine manufacturer and approval by ISC, be as close as possible to the procedure defined in 2.6. Therefore, values measured in this case may not be directly comparable with test-bed results because measured values are very much dependent on the test cycles.

6.3.9.3 If the number of measuring points on board is different than those on the test bed, the measuring points and the weighting factors are to be in accordance with the recommendations of the applicant for engine certification and approved by ISC taking into account the provisions of 6.4.6.

6.3.10 Calculation of gaseous emissions

The calculation procedure specified in chapter 5 is to be applied, taking into account the special requirements of this Simplified Measurement procedure.

6.3.11 Allowances

6.3.11.1 Due to the possible deviations when applying the simplified measurement procedures of this chapter on board a ship, an allowance of 10% of the applicable limit value may be accepted for confirmation tests and renewal, annual and intermediate surveys only.

6.3.11.2 The NO_x emission of an engine may vary depending on the ignition quality of the fuel oil and the fuel bound nitrogen. If there is insufficient information available on the influence of the ignition quality on the NO_x formation during the combustion process and the fuel bound nitrogen conversion rate also depends on the engine efficiency, an allowance of 10% may be granted for an onboard test run carried out on a RM-grade fuel oil (ISO 8217:2005) except that there will be no allowance for the pre-certification test on board. The fuel oil and gas fuel used are to be analysed for its composition of carbon, hydrogen, nitrogen, sulphur and, to the extent given in ISO 8217:2005 and ISO 8178-5:2008, any additional components necessary for a clear specification of the fuel oil and gas fuel.

6.3.11.3 In no case is the total granted allowance for both the simplification of measurements on board and the use of residual fuel oil of an ISO 8217:2005, RM-grade fuel oil, to exceed 15% of the applicable limit value.

6.4 Direct Measurement and Monitoring method

6.4.1 General

6.4.1.1 The shipowner is to have the option of direct measurement of NO_x emissions for onboard verification at the renewal, annual and intermediate surveys. Such data may take the form of spot checks logged with other engine operating data on a regular basis and over the full range of engine operation or may result from continuous monitoring and data storage. Data must be current (taken within the last 30 days) and must have been acquired using the test procedures cited as specified in 6.4. These monitoring records are to be kept on board for three months for verification purposes by the Parties in accordance with regulation 10 of MARPOL Annex VI. Data is also to be corrected for ambient conditions and fuel specification, and measuring equipment must be checked for correct calibration and operation, in accordance with the approved procedures given in the Onboard Operation Manual. Where exhaust gas after-treatment devices are fitted which influence the NO_x emissions, the measuring point(s) must be located downstream of such devices.

6.4.1.2 Due attention is to be given to the safety implications related to the handling and proximity of exhaust gases, the measurement equipment and the storage and use of cylindered pure and calibration gases. Sampling positions and access staging are to be such that this monitoring may be performed safely and will not interfere with the engine.

6.4.2 Emission species measurement

6.4.2.1 Onboard NO_x monitoring includes, as an absolute minimum, the measurement of gaseous emission concentrations of NO_x (as NO + NO_2).

6.4.2.2 If exhaust gas mass flow is to be determined in accordance with the carbon balance method in accordance with appendix 10 of the Guidelines, then CO_2 is also to be measured. Additionally CO, HC and O_2 may be measured.

6.4.3 Engine performance measurements

6.4.3.1 Table 6.4.3.1 lists the engine performance parameters that are to be measured, or calculated, and recorded at each mode point during onboard NO_x monitoring.

Engine parameters to be measured and recorded **Table 6.4.3.1**

Symbol	Parameter	Dimension
n_d	Engine speed	rpm
p_C	Charge air pressure at receiver	kPa
P	Brake power (as specified below)	kW
P_{aux}	Auxiliary power (if relevant)	kW
T_{SC}	Charge air temperature at receiver (if applicable)	K
T_{caclin}	Charge air cooler, coolant inlet temperature (if applicable)	℃
$T_{caclout}$	Charge air cooler, coolant outlet temperature (if applicable)	℃
T_{Sea}	Seawater temperature (if applicable)	℃
q_{mf}	Fuel oil flow (as specified below)	kg/h

6.4.3.2 Other engine settings necessary to define engine-operating conditions, e.g., waste-gate, charge air bypass and turbocharger status, are to be determined and recorded.

6.4.3.3 The settings and operating conditions of any NO_x reducing devices are to be determined and recorded.

6.4.3.4 If it is difficult to measure power directly, uncorrected brake power may be estimated by any other means as approved by ISC. Possible methods to determine brake power include, but are not limited to:

(1) indirect measurement in accordance with 6.3.3; or

(2) by estimation from nomographs.

6.4.3.5 The fuel oil flow (actual consumption rate) is to be determined by:

(1) direct measurement; or

(2) test-bed data in accordance with 6.3.1.4.

6.4.4 Ambient condition measurements

6.4.4.1 Table 6.4.4.1 lists the ambient condition parameters that are to be measured, or calculated, and recorded at each mode point during onboard NO_x monitoring.

Ambient condition parameters to be measured and recorded **Table 6.4.4.1**

Symbol	Parameter	Dimension
H_a	absolute humidity (mass of engine intake air water content related to mass of dry air)	g/kg
p_b	total barometric pressure (in ISO 3046-1, 1995: p_x=P_x=site ambient total pressure)	kPa
T_a	temperature at air inlet (in ISO 3046-1, 1995: T_x=TT_x=site ambient thermodynamic air temperature)	K

6.4.5 Engine performance and ambient condition monitoring equipment

6.4.5.1 The engine performance and ambient condition monitoring equipment are to be installed and maintained in accordance with manufacturers' recommendations such that requirements of section 1.3 and Tables 3 and 4 of appendix 8 of the Guidelines are met in respect of the permissible deviations.

6.4.6 Test cycles

6.4.6.1 Engine operation on board under a specified test cycle may not always be possible, but the test procedure, as approved by ISC, is to be as close as possible to the procedure defined in 2.6. Therefore, values measured in this case may not be directly comparable with test-bed results because measured values are very much dependant on the test cycle.

6.4.6.2 In the case of the E3 test cycle, if the actual propeller curve differs from the E3 curve, the load point used is to be set using the engine speed, or the corresponding mean effective pressure (MEP) or mean indicated pressure (MIP), given for the relevant mode of that cycle.

6.4.6.3 Where the number of measuring points on board is different from those on the test bed, the number of measurement points and the associated revised weighting factors is to be approved by ISC.

6.4.6.4 Further to 6.4.6.3 where the E2, E3 or D2 test cycles are applied, a minimum of load points are to be used of which the combined nominal weighting factor, as given in 2.6, is greater than 0.50.

6.4.6.5 Further to 6.4.6.3 where the C1 test cycle is applied, a minimum of one load point is to be used from each of the rated, intermediate and idle speed sections. If the number of measuring points on board is different from those on the test bed, the nominal weighting factors at each load point are to be increased proportionally in order to sum to unity (1.0).

6.4.6.6 With regard to the application of 6.4.6.3 guidance in respect of the selection of load points and revised weighting factors is given in section 6 of appendix 12 of the Guidelines.

6.4.6.7 The actual load points used to demonstrate compliance are to be within ± 5% of the rated power at the modal point except in the case of 100% load where the range is to be +0 to –10%. For example, at the 75% load point the acceptable range is to be 70% – 80% of rated power.

6.4.6.8 At each selected load point, except idle, and after the initial transition period (if applicable), the engine power is to be maintained at the load set point within a 5% coefficient of variance (%C.O.V.) over a 10-minute interval. A worked example of the coefficient of variance calculation is given in section 7 of appendix 12 of the Guidelines.

6.4.6.9 Regarding the C1 test cycle, the idle speed tolerance is to be declared, subject to the approval of ISC.

6.4.7 Test condition parameter

6.4.7.1 The test condition parameter specified in 5.3.1, is not to apply to onboard NO_x monitoring. Data under any prevailing ambient condition is to be acceptable.

6.4.8 Analyser in-service performance

6.4.8.1 Analysing equipment is to be operated in accordance with manufacturer's recommendations.

6.4.8.2 Prior to measurement, zero and span values are to be checked and the analysers are to be adjusted as necessary.

6.4.8.3 After measurement, analyser zero and span values are to be verified as being within that permitted by 5.8.3(7).

6.4.9 Data for emission calculation

6.4.9.1 The output of the analysers is to be recorded both during the test and during all response checks (zero and span). This data is to be recorded on a strip chart recorder or other types of data recording devices. Data recording precision is to be in accordance with 5.8.3(5).

6.4.9.2 For the evaluation of the gaseous emissions, a 1-Hertz minimum chart reading of a stable 10-minute sampling interval of each load point is to be averaged. The average concentrations of NO_x, and if required CO_2, and optionally CO, HC and O_2, are to be determined from the averaged chart readings and the corresponding calibration data.

6.4.9.3 As a minimum, emission concentrations, engine performance and ambient condition data are to be recorded over the aforementioned 10-minute period.

6.4.10 Exhaust gas flow rate

6.4.10.1 Exhaust gas flow rate is to be determined:

(1) in accordance with 5.6.1 or 5.6.2; or

(2) in accordance with 5.6.3 and appendix 10 of the Guidelines, with not measured species set to zero and c_{CO2d} set to 0.03%.

6.4.11 Fuel oil composition

6.4.11.1 Fuel oil composition, to calculate gas mass flow wet, q_{mf}, is to be provided by one of the following:

(1) fuel oil composition, carbon, hydrogen, nitrogen and oxygen, by analysis (default oxygen value may be adopted); or

(2) default values as given in Table 6.4.11.1.

Default fuel oil parameters **Table 6.4.11.1**

	Carbon	Hydrogen	Nitrogen	Oxygen
	w_{BET}	w_{ALF}	w_{DEL}	w_{EPS}
Distillate fuel oil (ISO 8217:2005 DM grade)	86.2%	13.6%	0.0%	0.0%
Residual fuel oil (ISO 8217:2005 RM grade)	86.1%	10.9%	0.4%	0.0%
Natural gas	75.0%	25.0%	0.0%	0.0%

Note: For other fuel oils, default value as approved by ISC.

6.4.12 Dry/wet correction

6.4.12.1 If not already measured on a wet basis, the gaseous emissions concentrations are to be converted to a wet basis according to:

(1) direct measurement of the water component; or

(2) dry/wet correction calculated in accordance with 5.7.1.

6.4.13 NO_x correction for humidity and temperature

6.4.13.1 NO_x correction for humidity and temperature is to be in accordance with 5.7.2. The reference charge air temperature (T_{SCRef}) is to be stated and approved by ISC. The T_{SCRef} values are to be referenced to 25℃ seawater temperature and in the application of the T_{SCRef} value due allowance is to be made for the actual seawater temperature.

6.4.14 Calculation of emission flow rates and specific emissions

6.4.14.1 The calculation of emission flow rates and specific emissions is to be in accordance with 5.7.3 and 5.7.4.

6.4.15 Limit value and allowances

6.4.15.1 In the case of the application of 6.4.6.3 the emission value gas_x obtained is, to be subject to the approval of ISC, be corrected as follows:

$$gas_{x,\text{corrected}} = gas_x \cdot 0.9 \qquad (21)$$

6.4.15.2 The emission value, gas_x or corrected gas_x as appropriate, are to be compared to the applicable NO_x emission limit value as given in chapter 2 together with the allowance values as given in 6.3.11.1, 6.3.11.2 and 6.3.11.3 in order to verify that an engine continues to comply with the requirements of chapter 2.

6.4.16 Data for demonstrating compliance

6.4.16.1 Compliance is required to be demonstrated at renewal, annual and intermediate surveys or following a substantial modification as per 1.3.1(4). In accordance with 6.4.1.1, data is required to be current; that is within 30 days. Data is required to be current; that is within 30 days. Data is required to be retained on board for at least three months. These time periods are to be taken to be when the ship is in operation. Data within that 30-day period either may be collected as a single test sequence across the required load points or may be obtained on two or more separate occasions when the engine load corresponds to that required by 6.4.6.

6.4.17 Form of approval

6.4.17.1 The Direct Measurement and Monitoring method are to be documented in an Onboard Monitoring Manual. The Onboard Monitoring Manual is to be submitted to ISC for approval. The approval reference of that Onboard Monitoring Manual is to be entered under section 3 of the Supplement to the EIAPP Certificate. ISC may issue a new EIAPP Certificate, with the details in section 3 of the Supplement duly amended, if the method is approved after the issue of the first EIAPP Certificate, i.e. following the pre-certification survey.

6.4.18 Survey of equipment and method

6.4.18.1 The survey of the Direct Measurement and Monitoring method is to take into account, but is not limited to:

(1) the data obtained and developed from the required measurements; and

(2) the means by which that data has been obtained, taking into account the information given in the Onboard Monitoring Manual as required by 6.4.14.

Chapter 7 Approval of Testing Organization

7.1 General requirements

7.1.1 Testing organization/unit of exhaust emission from marine diesel engine is to obtain the Approval Certificate for Testing Organization of Exhaust Emission from Marine Diesel Engines (hereinafter referred to as the Approval Certificate) issued by ISC according to the requirements of this chapter.

7.1.2 The testing organization/unit of exhaust emission from marine diesel engine (hereinafter referred to as the testing organization) approved by ISC is to carry out the emission testing faithfully to ensure the quality of the testing work and is to be responsible for the testing report issued.

7.2 Approval conditions

7.2.1 The testing organization is to have the following qualifications:

(1) the testing equipment as required by chapter 5 of the Guidelines;

(2) to own the technical management and operating personnel who are competent for the testing work; The relevant technician is to be trained and have the basic knowledge of emission of the engine, familiar with the emission testing technique and the testing equipment, skilled at the use of testing equipment;

(3) The testing organization is to establish an effective set of quality assurance system which is at least to include:

① to establish the operation guidance booklet which is to be strictly followed for the testing;

② to establish an effective system for equipment control, calibration and repair to ensure the testing equipment is effectively calibrated and applicable;

③ personnel training system as to ensure that the testing work is carried out by the competent technician who has been trained.

7.2.2 The testing organization is at least to be provided with the following information:

(1) relevant documents issued by IMO (such as MARPOL Annex VI, Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines);

(2) relevant information issued by ISC;

(3) operating manual for the testing equipment;

(4) the approved calculating procedures (where necessary).

7.2.3 The testing organization is to develop the testing report according to the sample of test report of the Guidelines (see appendix 9).

7.3 Procedures and requirements for approval

7.3.1 Units intended to obtain the approval of the qualification of testing organization by ISC are to submit the application in written form together with the following information:

(1) name and profile of the application unit;

(2) list of the testing equipment provided, including name, model, manufacture, testing method used, measuring range, record of the last calibration;

(3) quality control system required to be established;

(4) resume of testing personnel, training record (or certificate), education certificate, etc.;

(5) relevant calculation software and explanation of compilation (where applicable);

(6) list of relevant technical documents provided;

(7) test programme;

(8) other relevant information.

7.3.2 ISC is to review the relevant documents and information upon receipt of the above mentioned application and information.

7.3.3 After accepting the application, ISC is to appoint the personnel to carry out on-site audit for the application unit, including the audits of procedural documents and the process of on-site testing. Where any nonconformity is found or it is deemed unsatisfactory, the application unit is to be notified in written form and the unit is to take corrective actions and remove the nonconformities within a specified period.

7.3.4 ISC is to make assessment on the basis of the submitted information and audit report, and to issue the approval certificate if deemed satisfactory.

Appendix 1 Form of EIAPP Certificate (2000)

Form: CP168

INTERNATIONAL SHIP CLASSIFICATION

No. ____________

ENGINE INTERNATIONAL AIR POLLUTION PREVENTION CERTIFICATE

Issued under the provisions of the Protocol of 1997 to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as "the Convention") under the authority of the Government of :

____

by International Ship Classification

Engine manufacture ____

Model number ____

Serial number ____

Test cycle(s) ____

Rated power (kW) and speed (RPM) ______________________________________

Engine approval number ____

THIS IS TO CERTIFY:

1. That the above-mentioned marine diesel engine has been surveyed for pre-certification in accordance with the requirements of the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines made mandatory by Annex VI of the Convention; and
2. That the pre-certification survey shows that the engine, its components, adjustable features, and Technical File, prior to the engine's installation and/or service on board a ship, fully comply with the applicable regulation 13 of Annex VI of the Convention.

This certificate is valid for the life of the engine subject to surveys in accordance with regulation 5 of Annex VI of the Convention, installed in ships under the authority of this Government.

Issued at ______________________

Issued on______________________

____

Surveyor to International Ship Classification

Form: CP168

INTERNATIONAL SHIP CLASSIFICATION

No. ____________

SUPPLEMENT TO ENGINE INTERNATIONAL AIR POLLUTION PREVENTION CERTIFICATE (EIAPP CERTIFICATE)

RECORD OF CONSTRUCTION, TECHNICAL FILE AND MEANS OF VERIFICATION

In respect of the provisions of Annex VI of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997 relating thereto (hereinafter referred to as "the Convention") and of the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (hereinafter referred to as the "NO_x Technical Code").

Notes:
1. This Record and its attachments shall be permanently attached to the EIAPP Certificate. The EIAPP Certificate shall accompany the engine throughout its life and shall be available on board the ship at all times.
2. If the language of the original Record is neither English nor French, the test shall include a translation into one of these languages.
3. Unless otherwise stated, regulations mentioned in this record refer to regulations of Annex VI of the Convention and the requirements for an engine's Technical File and means of verifications refer to mandatory requirements from the NO_x Technical Code.

1. Particulars of the engine

1.1 Name and address of manufacturer____________________

1.2 Place of engine build/substantial modification____________________

1.3 Date of engine build/substantial modification____________________

1.4 Place of pre-certification survey____________________

1.5 Date of pre-certification survey____________________

1.6 Engine type and model number____________________

1.7 Engine serial number____________________

1.8 If applicable, the engine is a parent engine□or a member engine □of the following engine family□or engine group□____________________

1.9 Test cycle(s) (see chapter 3 of the NOx Technical Code)____________________

1.10 Rated Power (kW) and Speed (RPM)____________________

1.11 Engine approval number____________________

1.12 Specification(s) of test fuel____________________

1.13 NO_x reducing device designated approval number (if installed)____________________

1.14 Applicable NO_x Emission Limit (g/kWh)(regulation 13 of Annex VI)____________________

1.15 Engine's actual NO_x Emission Value (g/kWh)____________________

2. Particulars of the Technical File

2.1 Technical File identification/approval number____

2.2 Technical File approval date____

2.3 The Technical File, as required by chapter 2 of the NO_x Technical Code, is an essential part of the EIAPP Certificate and must always accompany an engine throughout its life and always be available on board a ship.

3. Specifications for the On-board NO_x Verification Procedures for the Engine Parameter Survey

3.1 On-board NO_x verification procedures identification/approval number____________________

3.2 On-board NO_x verification procedures approval date__________________________________

3.3 The specifications for the on-board NO_x verification procedures, as required by chapter 6 of the NO_x Technical Code, is an essential part of the EIAPP Certificate and must always accompany an engine through its life and always be available on board a ship.

THIS IS TO CERTIFY that this Record is correct in all respects.

Issued at_________________________________

Date of issue______________________________

Surveyor to International Ship Classification ____________________

Appendix 2 Form of Statement of Compliance (2000)

Form: CP167

INTERNATIONAL SHIP CLASSIFICATION

No. ____________

STATEMENT OF COMPLIANCE ON ENGINE INTERNATIONAL AIR POLLUTION PREVENTION

Issued under the provisions of the Protocol of 1997 to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as "the Convention") and IMO's Interim Guidelines for the Application of the NO_x Technical Code (MEPC/Circ.344), as an interim measure for the engine in compliance with the Protocol and subject to the issuance of EIAPP (Engine International Air Pollution Prevention) certificate pending entry into force of the Protocol, under the authority of the Government of:____________________by International Ship Classification.

Engine Manufacturer	Model Number	Serial Number	Test Cycle(s)	Rated Power (kW) and Speed (RPM)	Engine Approval Number

THIS IS TO CERTIFY:

1. That the above-mentioned marine diesel engine has been surveyed for pre-certification in accordance with the requirements of the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines made mandatory by Annex VI of the Convention; and
2. That the pre-certification survey shows that the engine, its components, adjustable features, and Technical File, prior to the engine's installation and/or service on board a ship, fully comply with the applicable regulation 13 of Annex VI of the Convention.

This Statement of compliance is valid for the life of the engine subject to surveys in accordance with regulation 5 of Annex VI of the Convention, installed in ships under the authority of this Government.

Issued at ____________________________

Date of issue ____________________________ Signed ________________________________

Form: CP167

INTERNATIONAL SHIP CLASSIFICATION

Supplement to Statement of Compliance on Engine International Air Pollution Prevention

RECORD OF CONSTRUCTION, TECHNICAL FILE AND MEANS OF VERIFICATION

No. ________________

In respect of the provisions of Annex VI of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997 relating thereto (hereinafter referred to as "the Convention") and of the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (hereinafter referred to as the "NO_x Technical Code").

Notes:
1 This Record and its attachments shall be permanently attached to the Statement of Compliance. The Statement of Compliance shall accompany the engine throughout its life and shall be available on board the ship at all times.
2 If the language of the original Record is neither English nor French, the text shall include a translation into one of these languages.
3 Unless otherwise stated, regulations mentioned in this record refer to regulations of Annex VI of the Convention and the requirements for an engine's Technical File and means of verifications refer to mandatory requirements from the NO_x Technical Code.

1 Particulars of the engine

1.1 Name and address of manufacturer________________

1.2 Place of engine build/substantial modification________________

1.3 Date of engine build/substantial modification________________

1.4 Place of pre-certification survey________________

1.5 Date of pre-certification survey________________

1.6 Engine type and model number________________

1.7 Engine serial number________________

1.8 If applicable, the engine is a parent engine □or a member engine □of the following engine family□or engine group□________________

1.9 Test cycle(s) (see chapter 3 of the NO_x Technical Code)________________

1.10 Rated Power (kW) and Speed (RPM)________________

1.11 Engine approval number________________

1.12 Specification(s) of test fuel________________

1.13 NO_x reducing device designated approval number (if installed)________________

1.14 Applicable NO_x Emission Limit (g/kWh) (regulation 13 of Annex VI)________________

1.15 Engine's actual NO_x Emission Value (g/kWh)________________

2 Particulars of the Technical File

2.1 Technical File identification/approval number________________

2.2 Technical File approval date________________

2.3 The Technical File, as required by chapter 2 of the NO_x Technical Code, is an essential part of the EIAPP Certificate and must always accompany an engine throughout its life and always be available on board a ship.

3 Specifications for the On-board NO_x Verification Procedures for the Engine Parameter Survey

3.1 On-board NO_x verification procedures identification/approval number ________________________

3.2 On-board NO_x verification procedures approval date ______________________________________

3.3 The specifications for the on-board NO_x verification procedures, as required by chapter 6 of the NO_x Technical Code, is an essential part of the EIAPP Certificate and must always accompany an engine through its life and always be available on board a ship.

THIS IS TO CERTIFY that this Record is correct in all respects.

Issued at __________________________

Date of issue __________________________ Signed ___________________________________

Appendix 3 Form of EIAPP Certificate (2009)

Form: CP268

INTERNATIONAL SHIP CLASSIFICATION

No._________

ENGINE INTERNATIONAL AIR POLLUTION PREVENTION CERTIFICATE (EIAPP)

Issued under the provisions of the Protocol of 1997, as amended, to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as "the Convention") under the authority of the Government of:

____

by International Ship Classification

Engine manufacture:____

Model number: ____

Serial number: ____

Test cycle(s): ____

Rated Power (kW) And Speed(RPM): ___________________________________

Engine Approval Number: ____

THIS IS TO CERTIFY:

1. That the above-mentioned marine diesel engine has been surveyed for pre-certification in accordance with the requirements of the Revised Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (2008) made mandatory by Annex VI of the Convention; and
2. That the pre-certification survey shows that the engine, its components, adjustable features, and Technical File, prior to the engine's installation and/or service on board a ship, fully comply with the applicable regulation 13 of Annex VI of the Convention.

This Statement is valid for the life of the engine subject to surveys in accordance with regulation 5 of Annex VI of the Convention.

Issued at ________________________

Issued on ________________________

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Surveyor to International Ship Classification

Form: CP268

INTERNATIONAL SHIP CLASSIFICATION

No._____________

Supplement to Engine International Air Pollution Prevention Certificate

RECORD OF CONSTRUCTION, TECHNICAL FILE AND MEANS OF VERIFICATION

Notes: 1 This Record and its attachments shall be permanently attached to the EIAPP Certificate. The EIAPP Certificate shall accompany the engine throughout its life and shall be available on board the ship at all times. 2 The Record shall be at least in English, French or Spanish. If an official language of the issuing country is also used, this shall prevail in case of a dispute or discrepancy. 3 Unless otherwise stated, regulations mentioned in this Record refer to regulations of Annex VI of the Convention and the requirements for an engine's Technical File and means of verifications refer to mandatory requirements from the Revised NO_x Technical Code (2008).

1 Particulars of the engine

1.1 Name and address of manufacturer:____

1.2 Place of engine build:____

1.3 Date of engine build:____

1.4 Place of pre-certification survey:____

1.5 Date of pre-certification survey:____

1.6 Engine type and model number:____

1.7 Engine serial number:____

1.8 If applicable, the engine is a Parent Engine□ or a Member Engine□ of the following Engine Family□ or Engine Group□____

1.9 Individual Engine or Engine Family / Engine Group details:

1.9.1 Approval reference:____

1.9.2 Rated power (kW) and rated speed (rpm) values or ranges:____________________________

1.9.3 Test cycle(s) :____

1.9.4 Parent Engine(s) test fuel oil specification:____

1.9.5 Applicable NO_x emission limit (g/kWh), regulation 13.3, 13.4, or 13.5.1 (delete as appropriate):

____

1.9.6 Parent Engine(s) emission value (g/kWh):____

2. Particulars of the Technical File

The Technical File, as required by chapter 2 of the NO_x Technical Code, is an essential part of the EIAPP Certificate and must always accompany an engine throughout its life and always be available on board a ship.

2.1 Technical File identification/approval number:____

2.2 Technical File approval date:____

3. Specifications for the onboard NOx verification procedures

The specifications for the onboard NO_x verification procedures, as required by chapter 6 of the NO_x Technical Code, are an essential part of the EIAPP Certificate and must always accompany an engine through its life and always be available on board a ship.

3.1 Engine Parameter Check method:

3.1.1 Identification/approval number:____

3.1.2 Approval date:____

3.2 Direct Measurement and Monitoring method:

3.2.1 Identification/approval number:____

3.2.2 Approval date:____

Alternatively the Simplified Measurement method in accordance with 6.3 of the NOx Technical Code may be utilized.

Issued at ________________________

Issued on ________________________

____

Surveyor to International Ship Classification

Appendix 4   Form of Statement of Compliance (2009)

Form: CP267

INTERNATIONAL SHIP CLASSIFICATION

No.____________

STATEMENT OF COMPLIANCE ON ENGINE INTERNATIONAL AIR POLLUTION PREVENTION

（SCEIAPP）

Issued under the provisions of the Protocol of 1997, as amended, to amend the International Convention for the Prevention of Pollution from Ships, 1973,as modified by the Protocol of 1978 related thereto (hereinafter referred to as “the Convention”) at the request of:___

by International Ship Classification

Engine manufacture:____

Model number:____

Serial number:____

Test cycle(s):____

Rated Power(kW) And Speed(RPM):____

Engine Approval Number:____

THIS IS TO CERTIFY:

1. That the above-mentioned marine diesel engine has been surveyed for pre-certification in accordance with the requirements of the Revised Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (2008) made mandatory by Annex VI of the Convention; and
2. That the pre-certification survey shows that the engine, its components, adjustable features, and Technical File, prior to the engine’s installation and/or service on board a ship, fully comply with the applicable regulation 13 of Annex VI of the Convention.

This Statement is valid for the life of the engine subject to surveys in accordance with regulation 5 of Annex VI of the Convention.

Issued at ________________________

Issued on ________________________

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Surveyor to International Ship Classification

Form: CP267

INTERNATIONAL SHIP CLASSIFICATION

No.____________

Supplement to Statement of Compliance on
Engine International Air Pollution Prevention

RECORD OF CONSTRUCTION, TECHNICAL FILE AND MEANS OF VERIFICATION

Notes:
1 This Record and its attachments shall be permanently attached to the SCEIAPP. The SCEIAPP shall accompany the engine throughout its life and shall be available on board the ship at all times.

2 The Record shall be at least in English, French or Spanish. If an official language of the issuing country is also used, this shall prevail in case of a dispute or discrepancy.

3 Unless otherwise stated, regulations mentioned in this Record refer to regulations of Annex VI of the Convention and the requirements for an engine's Technical File and means of verifications refer to mandatory requirements from the Revised NO_x Technical Code (2008).

1. Particulars of the engine

1.1 Name and address of manufacturer :____

1.2 Place of engine build :____

1.3 Date of engine build:____

1.4 Place of pre-certification survey:____

1.5 Date of pre-certification survey:____

1.6 Engine type and model number:____

1.7 Engine serial number:____

1.8 If applicable, the engine is a Parent Engine□ or a Member Engine□ of the following Engine Family□ or Engine Group□____

1.9 Individual Engine or Engine Family / Engine Group details:

1.9.1 Approval reference:____

1.9.2 Rated power (kW) and rated speed (rpm) values or ranges:______________________________

1.9.3 Test cycle(s) :____

1.9.4 Parent Engine(s) test fuel oil specification:____

1.9.5 Applicable NO_x emission limit (g/kWh), regulation 13.3, 13.4, or 13.5.1 (delete as appropriate):

____

1.9.6 Parent Engine(s) emission value (g/kWh):____

2. Particulars of the Technical File

The Technical File, as required by chapter 2 of the NO_x Technical Code, is an essential part of the SCEIAPP and must always accompany an engine throughout its life and always be available on board a ship.

2.1 Technical File identification/approval number:_______________________________________

2.2 Technical File approval date:____

3. Specifications for the onboard NO_x verification procedures

The specifications for the onboard NO_x verification procedures, as required by chapter 6 of the NO_x Technical Code, are an essential part of the SCEIAPP and must always accompany an engine through its life and always be available on board a ship.

3.1 Engine Parameter Check method:

3.1.1 Identification/approval number:____

3.1.2 Approval date:____

3.2 Direct Measurement and Monitoring method:

3.2.1 Identification/approval number:____

3.2.2 Approval date:____

Alternatively the Simplified Measurement method in accordance with 6.3 of the NO_x Technical Code may be utilized.

Issued at ________________________

Issued on ________________________

____

Surveyor to International Ship Classification

Appendix 5 Flowcharts for survey and certification of marine diesel engines

(*Refer to 3.4.11 and 3.5.14 of the Guidelines*)

Guidance for compliance with survey and certification of marine diesel engines, as described in chapter 3 of the Guidelines, is given in Figures 1, 2 and 3 of this Appendix:

Figure 1: Pre-certification survey at the manufacturer's facility

Figure 2: Initial survey on board a ship

Figure 3: Renewal, annual or intermediate survey on board a ship

Note: These flowcharts do not show the criteria for the certification of an Existing Engine as required by 2.4.

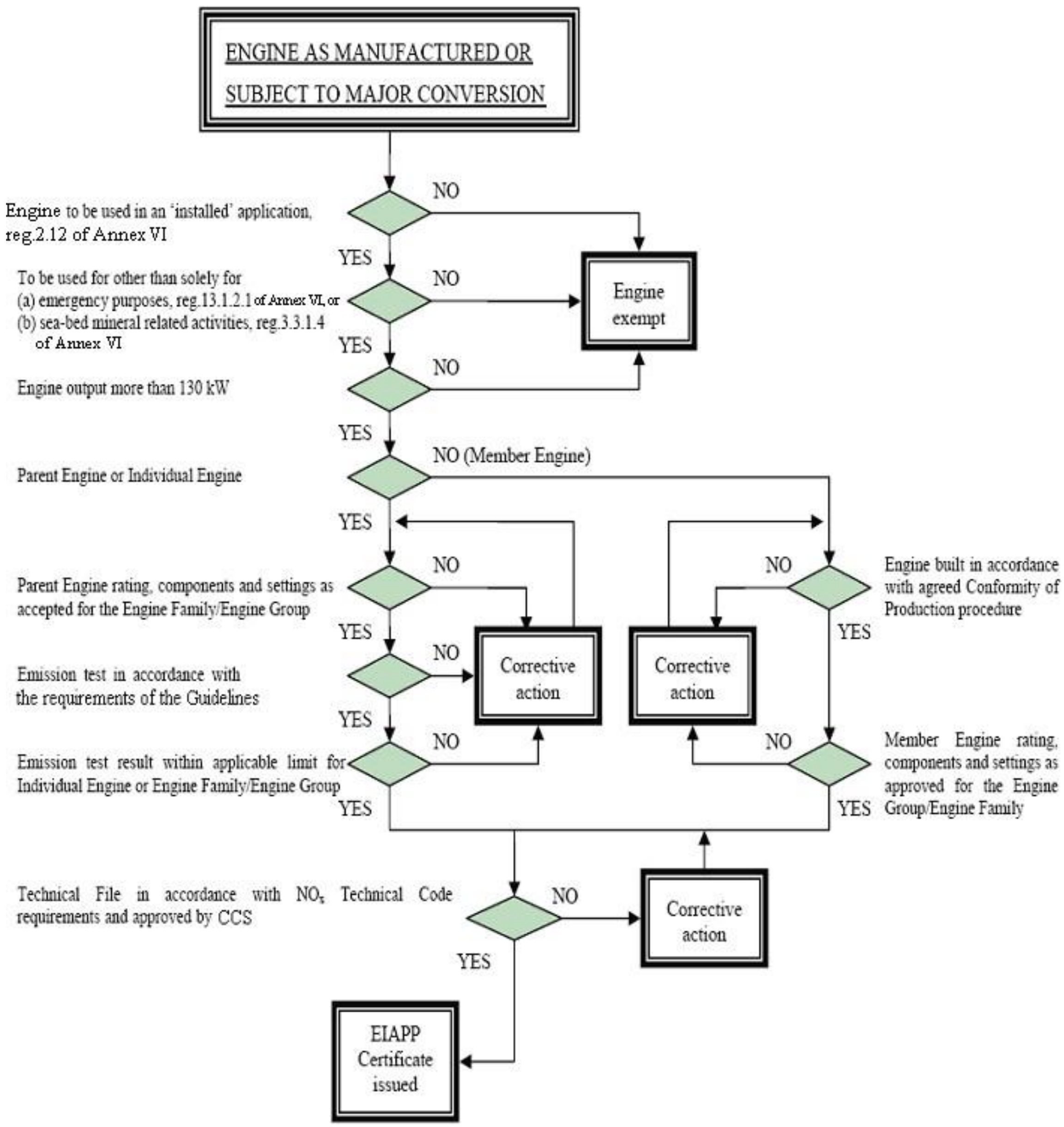

Figure 1 – Pre-certification survey at the manufacturer's facility

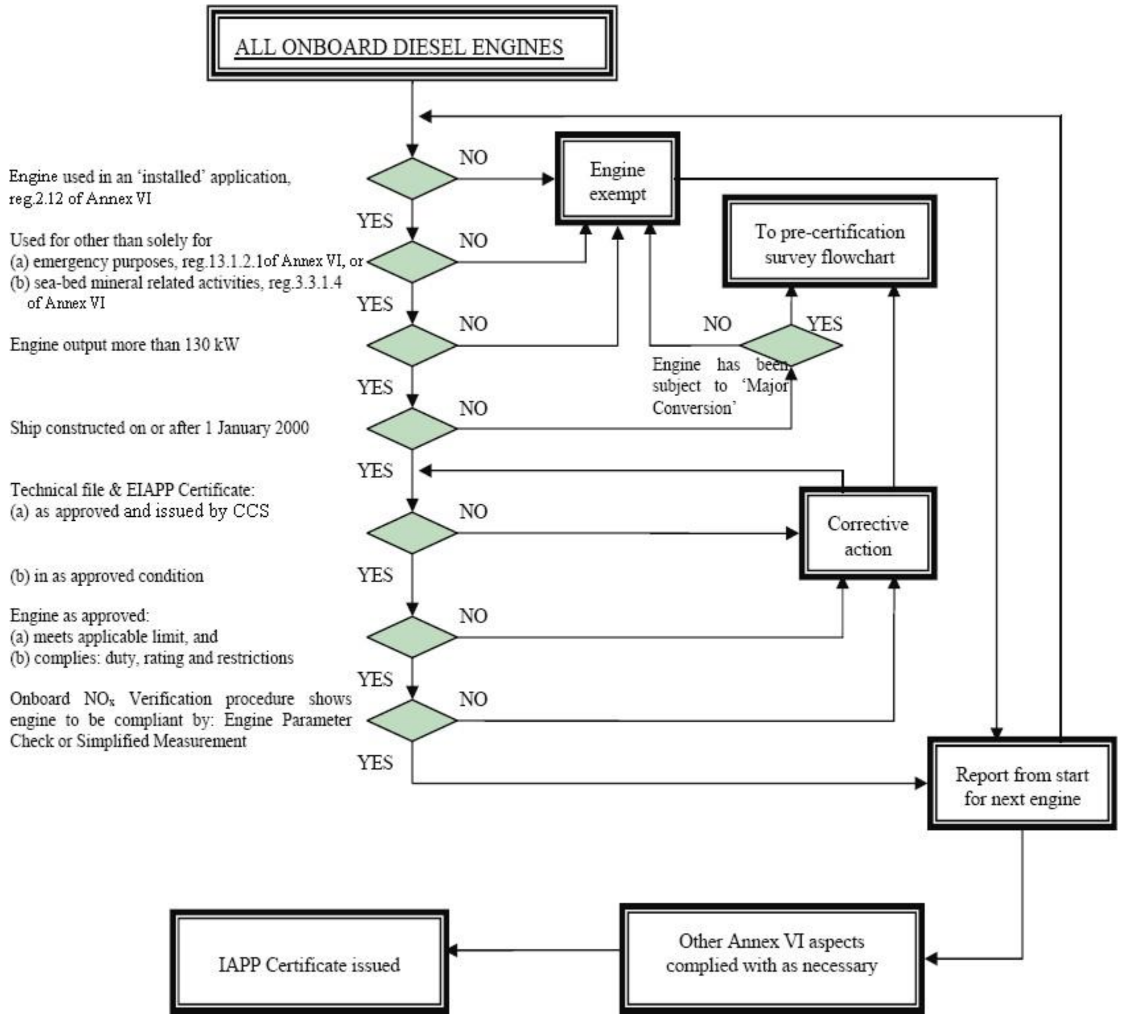

Figure 2 – Initial survey on board a ship

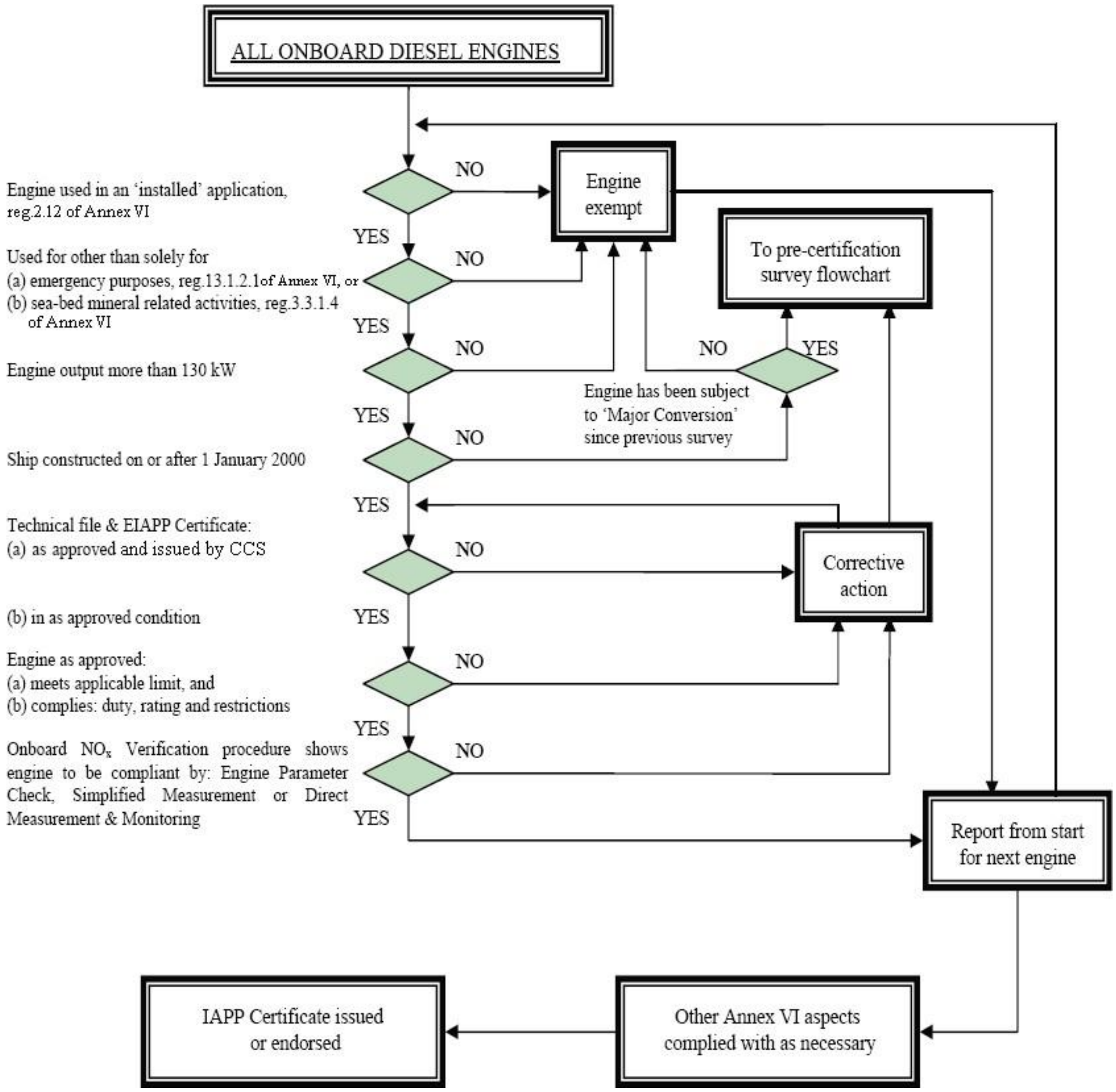

Figure 3 – Renewal, annual or intermediate survey on board a ship

Appendix 6 Main content of test programme (for reference)

1 Basic information of the test

1.1 Particulars of the engine: model, power, speed, application, the purpose of the test (individual/parent engine).

1.2 Time, place and the host of the test.

1.3 Testing organization.

2 Test conditions

2.1 Power system, pressure charging system, air intake system, fuel supply system.

2.2 Fuel oil for the test.

2.3 Diagrammatic drawing of the exhaust system and arrangement for the measuring points.

2.4 Brief introduction of the measuring system (measurement of the gaseous emissions and other parameters).

3 Measuring instrument (name, model, precision, not including conventional measuring instrument)

4 Content and procedure of the test

4.1 The procedures contained and the time arrangements are as follows:

(1) warming-up of the engine;

(2) preparation of the measuring system (warming-up, calibration and testing);

(3) test procedures according to the test cycle;

(4) calibration of the measuring system after the completion of the testing.

4.2 Record method of the test data (recording form of the parameters may be used).

Appendix 7 Specifications for analysers to be used in the determination of gaseous components of marine diesel engine emissions

(Refer to chapter 5 of the Guidelines)

1. General

1.1 The components included in an exhaust gas analysis system for the determination of the concentrations of CO, CO_2, NO_x, HC and O_2 are shown in Figure 1. All components in the sampling gas path must be maintained at the temperatures specified for the respective systems.

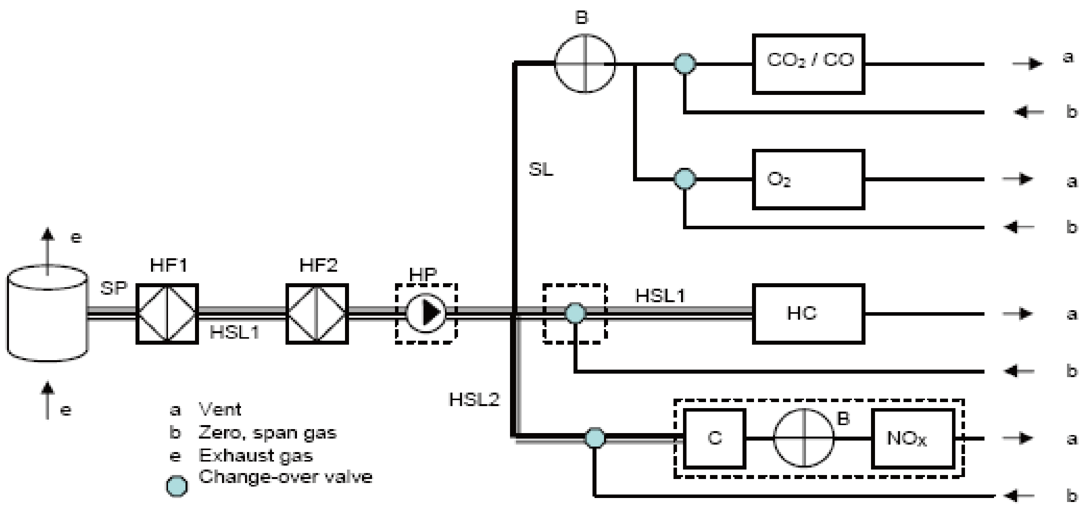

Figure 1 – Arrangement of exhaust gas analysis system

1.2 An exhaust gas analysis system is to include the following components. In accordance with chapter 5 of the Guidelines equivalent arrangements and components may, subject to approval by ISC, be accepted.

1.2.1 SP – Raw exhaust gas sampling probe

A stainless steel, straight, closed-end, multi-hole probe. The inside diameter is not to be greater than the inside diameter of the sampling line. The wall thickness of the probe is not to be greater than 1 mm. There are to be a minimum of three holes in three different radial planes sized to sample approximately the same flow.

For the raw exhaust gas, the sample for all components may be taken with one sampling probe or with two sampling probes located in close proximity and internally split to the different analysers.

Note: If exhaust pulsations or engine vibrations are likely to affect the sampling probe, the wall thickness of the probe may be enlarged subject to the approval of ISC.

1.2.2 HSL1 – Heated sampling line

The sampling line provides a gas sample from a single probe to the split point(s) and the HC analyser. The sampling line is to be made of stainless steel or PTFE and have a 4 mm minimum and a 13.5 mm maximum inside diameter.

The exhaust gas temperature at the sampling probe is not to be less than 190℃. The temperature of the exhaust gas from the sampling point to the analyser is to be maintained by using a heated filter and a heated transfer line with a wall temperature of 190℃ ±10℃.

If the temperature of the exhaust gas at the sampling probe is above 190℃, a wall temperature greater than 180℃ is to be maintained.

Immediately before the heated filter and the HC analyser a gas temperature of 190℃ ± 10℃ is to be maintained.

1.2.3 HSL2 – Heated NO_x sample line

The sampling line is to be made of stainless steel or PTFE and maintain a wall temperature of 55℃ to 200℃, up to the converter C when using a cooling unit B, and up to the analyser when a cooling unit B is not used.

1.2.4 HF1 – Heated pre-filter (optional)

The required temperature is to be the same as for HSL1.

1.2.5 HF2 – Heated filter

The filter is to extract any solid particles from the gas sample before the analyser. The temperature is to be the same as for HSL1. The filter is to be changed as necessary.

1.2.6 HP – Heated sampling pump (optional)

The pump is to be heated to the temperature of HSL1.

1.2.7 SL – Sampling line for CO, CO_2 and O_2

The line is to be made of PTFE or stainless steel. It may be heated or unheated.

1.2.8 CO_2/CO – Carbon dioxide and carbon monoxide analysers

Non-dispersive infrared (NDIR) absorption. Either separate analysers or two functions incorporated into a single analyser unit.

1.2.9 HC – Hydrocarbon analyser

Heated flame ionization detector (HFID). The temperature is to be kept at 180℃ to 200℃.

1.2.10 NO_x – Nitrogen oxides analyser

Chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD). If a HCLD is used, it is to be kept at a temperature of 55℃ to 200℃.

Note: In the arrangement shown NO_x is measured on a dry basis. NO_x may also be measured on a wet basis in which case the analyser is to be of the HCLD type.

1.2.11 C – converter

A converter is to be used for the catalytic reduction of NO_2 to NO prior to analysis in the CLD or HCLD.

1.2.12 O_2 – Oxygen analyser

Paramagnetic detector (PMD), zirconium dioxide (ZRDO) or electrochemical sensor (ECS). ZRDO is not to be used for dual fuel or gas-fuelled engines.

Note: In the arrangement shown O_2 is measured on a dry basis. O_2 may also be measured on a wet basis in which case the analyser is to be of the ZRDO type.

1.2.13 B – cooling unit

To cool and condense water from the exhaust sample. The cooler is to be maintained at a temperature of 0℃ to 4℃ by ice or refrigerator. If water is removed by condensation, the sample gas temperature or dew point is to be monitored either within the water trap or downstream. The sample gas temperature or dew point is not to exceed 7℃.

1.3 The analysers are to have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (see 1.6) and 5.8.3(5) of the Guidelines. It is recommended that the analysers be operated such that the measured concentration falls between 15% and 100% of full scale. Where full scale refers to the measurement range used.

1.4 If the full scale value is 155 ppm (or ppmC) or less, or if read-out systems (computers, data loggers) that provide sufficient accuracy and resolution below 15% of full scale are used, concentrations below 15% of full scale are also acceptable. In this case, additional calibrations are to be made to ensure the accuracy of the calibration curves.

1.5 The electromagnetic compatibility (EMC) of the equipment is to be such as to minimize additional errors.

1.6 Accuracy

1.6.1 Definitions

ISO 5725-1: Technical Corrigendum 1: 1998, Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions, Technical Corrigendum 1.

ISO 5725-2: 1994, Accuracy (trueness and precision) of measurement methods and results – Part 2: A basic method for the determination of repeatability and reproducibility of a standard measurement method.

1.6.2 An analyser is not to deviate from the nominal calibration point by more than ± 2% of the reading over the whole measurement range except zero, or ± 0.3% of full scale whichever is larger. The accuracy is to be determined according to the calibration requirements laid down in section 5 of appendix 8 of the Guidelines.

1.7 Precision

The precision, defined as 2.5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, is to be not greater than ± 1% of full scale concentration for each range used above 100 ppm (or ppmC) or ±2% of each range used below 100 ppm (or ppmC).

1.8 Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10-second period is not to exceed 2% of full scale on all ranges used.

1.9 Zero drift

Zero response is defined as the mean response, including noise, to a zero gas during a 30-second time interval. The drift of the zero response during a one-hour period is to be less than 2% of full scale on the lowest range used.

1.10 Span drift

Span response is defined as the mean response, including noise, to a span gas during a 30-second time interval. The drift of the span response during a one-hour period is to be less than 2% of full scale on the lowest range used.

2 Gas drying

Exhaust gases may be measured wet or dry. A gas drying device, if used, is to have a minimal effect on the composition of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

3 Analysers

Sections 3.1 to 3.5 describe the measurement principles to be used. The gases to be measured are to be analysed with the following instruments. For non-linear analysers, the use of linearizing circuits is permitted.

3.1 Carbon monoxide (CO) analysis

The carbon monoxide analyser is to be of the non-dispersive infrared (NDIR) absorption type.

3.2 Carbon dioxide (CO_2) analysis

The carbon dioxide analyser is to be of the non-dispersive infrared (NDIR) absorption type.

3.3 Hydrocarbon (HC) analysis

The hydrocarbon analyser is to be of the heated flame ionization detector (HFID) type with detector, valves, pipe-work and associated components heated so as to maintain a gas temperature of 190℃ ± 10℃. Optionally, for gas-fuelled engines (without liquid pilot injection), the hydrocarbon analyser may be of the non-heated flame ionization detector (FID) type.

3.4 Nitrogen oxides (NO_x) analysis

The nitrogen oxides analyser is to be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO_2/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with converter maintained above 55℃ is to be used, provided the water quench check (see section 9.2.2 of appendix 8 of the Guidelines) is satisfied. For both CLD and HCLD, the sampling path is to be maintained at a wall temperature of 55℃ to 200℃ up to the converter for dry measurement, and up to the analyser for wet measurement.

3.5 Oxygen (O_2) analysis

The oxygen analyser is to be of the paramagnetic detector (PMD), zirconium dioxide (ZRDO) or electrochemical sensor (ECS) type. ZRDO is not to be used for dual fuel or gas-fuelled engines.

Appendix 8 Calibration of the analytical instruments

1 General requirements

1.1 Each analyser used for the measurement of an engine's parameters is to be calibrated as often as necessary in accordance with the requirements of this appendix.

1.2 All results of measurements, test data or calculations required by this appendix are to be recorded in the engine's test report in accordance with section 5.9 of the Guidelines.

1.3 Accuracy of analytical instruments

1.3.1 The calibration of all measuring instruments is to comply with the requirements as set out in Tables 1, 2, 3 and 4 and is to be traceable to standards recognized by ISC.

1.3.2 The instruments are to be calibrated:

(1) in time intervals not greater than as given in Tables 1, 2, 3 and 4; or

(2) in accordance with alternative calibration procedures and validity periods subject to such proposals being submitted in advance of the tests and approved by ISC.

Note: The deviations given in Tables 1, 2, 3, and 4 refer to the final recorded value, which is inclusive of the data acquisition system.

Permissible deviations of instruments for engine related parameters for measurements on a test bed **Table 1**

No.	Measurement instrument	Permissible deviation	Calibration validity period (months)
1	Engine speed	± 2% of reading or ± 1% of engine's maximum value, whichever is larger	3
2	Torque	± 2% of reading or ± 1% of engine's maximum value, whichever is larger	3
3	Power (where measured directly)	± 2% of reading or ± 1% of engine's maximum value, whichever is larger	3
4	Fuel consumption	± 2% of engine's maximum value	6
5	Air consumption	± 2% of reading or ± 1% of engine's maximum value, whichever is larger	6
6	Exhaust gas flow	± 2.5% of reading or ± 1.5% of engine's maximum value, whichever is larger	6

Permissible deviations of instruments for other essential parameters for measurements on a test bed **Table 2**

No.	Measurement instrument	Permissible deviation	Calibration validity period (months)
1	Temperatures ≤ 327℃	±2℃ absolute	3
2	Temperatures > 327℃	±1% of reading	3
3	Exhaust gas pressure	±0.2 kPa absolute	3
4	Charge air pressure	±0.3 kPa absolute	3
5	Atmospheric pressure	±0.1 kPa absolute	3
6	Other pressures ≤ 1000 kPa	±20 kPa absolute	3
7	Other pressures > 1000 kPa	±2% of reading	3
8	Relative humidity	±3% absolute	1

Permissible deviations of instruments for engine related parameters for measurements on board a ship when the engine is already pre-certified **Table 3**

No.	Measurement instrument	Permissible deviation(±% of engine's maximum value)	Calibration validity period (months)
1	Engine speed	2%	12
2	Torque	5%	12

3	Power (where measured directly)	5%	12
4	Fuel consumption	4%	12
5	Air consumption	5%	12
6	Exhaust gas flow	5%	12

Permissible deviations of instruments for other essential parameters for measurements on board a ship when the engine is already pre-certified **Table 4**

No.	Measurement instrument	Permissible deviation	Calibration validity period (months)
1	Temperatures ≤ 327℃	±2℃ absolute	12
2	Temperatures > 327℃	±15℃ absolute	12
3	Exhaust gas pressure	± 5% of engine's maximum value	12
4	Charge air pressure	± 5% of engine's maximum value	12
5	Atmospheric pressure	±0.5% of reading	12
6	Other pressures	±5 % of reading	12
7	Relative humidity	±3% absolute	6

2 Calibration gases

2.1 The shelf life of all calibration gases and span and zero check gases is to be respected. The expiry date of the calibration gases and the zero and span check gases, stated by the manufacturer, is to be recorded.

2.2 Pure gases (including zero check gases)

2.2.1 The required purity of the gases is defined by the contamination limits given below.

(1) purified nitrogen (contamination ≤ 1 ppmC, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO);

(2) purified oxygen (purity > 99.5% volume O_2);

(3) hydrogen-helium mixture (40 ± 2% hydrogen, balance helium), (contamination ≤ 1 ppmC, ≤ 400 ppm CO_2); and

(4) purified synthetic air (contamination ≤ 1 ppmC, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO (oxygen content 18% – 21% volume).

2.3 Calibration and span gases

2.3.1 Mixtures of gases having the following chemical compositions are to be available:

(1) CO and purified nitrogen;

(2) NO_x and purified nitrogen the amount of NO_2 contained in this calibration gas is not to exceed 5% of the NO content);

(3) O_2 and purified nitrogen;

(4) CO_2 and purified nitrogen; and

(5) CH_4 and purified synthetic air or C_3H_8 and purified synthetic air.

2.3.2 Other gas combinations are allowed provided the gases do not react with one another.

2.3.3 The true concentration of a calibration and span gas must be within ± 2% of the nominal value. All concentrations of calibration and span gases are to be given on a volume basis (volume percent or volume ppm).

2.3.4 The gases used for calibration and span may also be obtained by means of precision blending devices (gas dividers), diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the blended calibration gases is accurate to within ±2%. This accuracy implies that primary gases used for blending must be known to an accuracy of at least ±1%, traceable to national or international gas standards. The verification is to be performed at between 15 and 50% of full scale for each calibration incorporating a blending device. Optionally, the blending device may be checked with an instrument which by nature is linear, e.g., using NO gas with a CLD. The span value of the instrument is to be adjusted with the span gas directly connected to the instrument. The blending device is to be checked at the used settings and the nominal value is to be compared to the measured concentration of the instrument. This difference in each point is to be within ±1% of the nominal value. This linearity check of the gas divider is not to be performed with a gas analyser which was previously linearized with the same gas divider.

2.3.5 Oxygen interference check gases are to contain propane or methane with 350 ppmC ±75 ppmC hydrocarbon. The concentration is to be determined to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic bleeding. Nitrogen is to be the predominant diluent with the balance oxygen. Blends required are listed in Table 5.

Oxygen interference check gases Table 5

O_2 concentration (%)	Balance
21（20~22）	Nitrogen
10（9~11）	Nitrogen
5（4~6）	Nitrogen

3 Operating procedure for analysers and sampling system

3.1 The operating procedure for analysers is to follow the start-up and operating instructions of the instrument manufacturer. The minimum requirements given in sections 4 to 9 are to be included.

4 Leakage test

4.1 A system leakage test is to be performed. The probe is to be disconnected from the exhaust system and the end plugged. The analyser pump is to be switched on. After an initial stabilization period all flow meters are to be read zero. If not, the sampling lines are to be checked and the fault corrected.

4.2 The maximum allowable leakage rate on the vacuum side is to be 0.5% of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

4.3 Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas. If after an adequate period of time the reading shows a lower concentration compared to the introduced concentration, this points to calibration or leakage problems.

4.4 Other arrangements may be acceptable subject to approval of ISC.

5 Calibration procedure

5.1 Instrument assembly

The instrument assembly is to be calibrated and the calibration curves checked against standard gases. The same gas flow rates are to be used as when sampling exhaust.

5.2 Warming-up time

The warming-up time is to be according to the recommendations of the analyser’s manufacturer. If not specified, a minimum of two hours is recommended for warming up the analysers.

5.3 NDIR and (H)FID analysers

The NDIR analyser is to be tuned, as necessary. The (H)FID flame is to be optimized as necessary.

5.4 Calibration

5.4.1 Each normally used operating range is to be calibrated. Analysers are to be calibrated not more than 3 months before being used for testing or whenever a system repair or change is made that can influence calibration, or as per provided for by 1.3.2(2).

5.4.2 Using purified synthetic air (or nitrogen) the CO, CO_2, NO_x and O_2 analysers are to be set at zero. The (H)FID analyser is to be set to zero using purified synthetic air.

5.4.3 The appropriate calibration gases are to be introduced to the analysers, the values recorded, and the calibration curve established according.

5.4.4 The zero setting is to be rechecked and the calibration procedure repeated, if necessary.

5.5 Establishment of the calibration curve

5.5.1 General requirements

5.5.1.1 The calibration curve is to be established by at least 6 calibration points (excluding zero) approximately equally spaced over the operating range from zero to the highest value expected during emissions testing.

5.5.1.2 The calibration curve is to be calculated by the method of least-squares. A best-fit linear or non-linear equation may be used.

5.5.1.3 The calibration points are not to differ from the least-squares best-fit line by more than ± 2% of reading or ±0.3% of full scale, whichever is larger.

5.5.1.4 The zero setting is to be rechecked and the calibration procedure repeated, if necessary.

5.5.1.5 If it can be shown that alternative calibration methods (e.g., computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used subject to the approval by ISC.

6 Verification of the calibration

6.1 Each normally used operating range is to be checked prior to each analysis in accordance with the following procedure:

(1) the calibration is to be checked by using a zero gas and a span gas whose nominal value is to be more than 80% of full scale of the measuring range; and

(2) if, for the two points considered, the value found does not differ by more than ± 4% of full scale from the declared reference value, the adjustment parameters may be modified. If this is not the case, a new calibration curve is to be established in accordance with 5.5 above.

7 Efficiency test of the NO_x converter

The efficiency of the converter used for the conversion of NO_2 into NO is to be tested as given in 7.1 to 7.8 below.

7.1 Test set-up

Using the test set-up as schematically shown in Figure 1 and the procedure below, the efficiency of converter is to be tested by means of an ozonator.

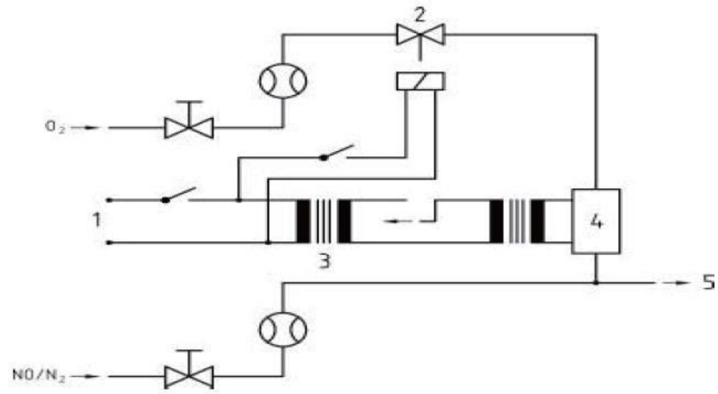

Figure 1 – Schematic representation of NO_2 converter efficiency device
1 AC 2 Solenoid valve 3 Variac 4 Ozonator 5 To analyser

7.2 Calibration

The CLD and the HCLD are to be calibrated in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80% of the operating range and the NO_2 concentration of the gas mixture to less than 5% of the NO concentration). The NO_x analyser must be in the NO mode so that the span gas does not pass through the converter. The indicated concentration is to be recorded.

7.3 Calculation

The efficiency of the NO_x converter is to be calculated as follows:

$$E_{NOx} = (1 + \frac{a-b}{c-d}) \cdot 100$$

where: a = NO_x concentration according to 7.6 below
b = NO_x concentration according to 7.7 below
c = NO concentration according to 7.4 below
d = NO concentration according to 7.5 below

7.4 Adding of oxygen

7.4.1 Via a T-fitting, oxygen or zero air is added continuously to the gas flow until the concentration indicated is about 20% less than the indicated calibration concentration given in 7.2 above. The analyser must be in the NO mode.

7.4.2 The indicated concentration (c) is to be recorded. The ozonator must be kept deactivated throughout the process.

7.5 Activation of the ozonator

The ozonator is then to be activated to generate enough ozone to bring the NO concentration down to about 20% (minimum 10%) of the calibration concentration given in 7.2 above. The indicated concentration (d) is to be recorded. The analyser must be in the NO mode.

7.6 NO_x mode

The NO analyser is then to be switched to the NO_x mode so that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. The indicated concentration (a) is to be recorded. The analyser must be in the NO_x mode.

7.7 Deactivation of the ozonator

The ozonator is then deactivated. The mixture of gases described in 7.6 above passes through the converter into the detector. The indicated concentration (b) is to be recorded. The analyser is in the NO_x mode.

7.8 NO mode

Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air is also to be shut off. The NO_x reading of the analyser is not to deviate by more than 5% from the value measured according to 7.2 above. The analyser must be in the NO mode.

7.9 The efficiency of the converter is to be tested prior to each calibration of the NO_x analyser.

7.10 The efficiency of the converter is not to be less than 90%, but a higher efficiency of 95% is strongly recommended.

7.11 If, with the analyser in the most common range, the NO_x converter cannot give a reduction from 80% to 20% according to 7.2, then the highest range which will give the reduction is to be used.

8 Adjustment of the (H)FID

8.1 Optimization of the detector response

8.1.1 The (H)FID is to be adjusted as specified by the instrument manufacturer. A propane in air span gas is to be used to optimize the response on the most common operating range.

8.1.2 With the fuel and air flow rates set at the manufacturer's recommendations, a 350 ± 75 ppmC span gas is to be introduced to the analyser. The response at a given fuel flow is to be determined from the difference between the span gas response and the zero gas response. The fuel flow is to be incrementally adjusted above and below the manufacturer's specification. The span and zero response at these fuel flows are to be recorded. The difference between the span and zero response is to be plotted and the fuel flow adjusted to the rich side of the curve. This is the initial flow rate setting which may need further optimization depending on the results of the hydrocarbon response factors and the oxygen interference check according to 8.2 and 8.3.

8.1.3 If the oxygen interference or the hydrocarbon response factors do not meet the following specifications, the air flow is to be incrementally adjusted above and below the manufacturer's specifications, 8.2 and 8.3 for each flow.

8.1.4 The optimization may optionally be conducted using alternative procedures subject to the approval of ISC.

8.2 Hydrocarbon response factors

8.2.1 The analyser is to be calibrated using propane in air and purified synthetic air, according to 5.

8.2.2 Response factors are to be determined when introducing an analyser into service and after major service intervals. The response factor (r_h) for a particular hydrocarbon species is the ratio of the (H)FID ppmC reading to the gas concentration in the cylinder expressed in terms of ppmC.

8.2.3 The concentration of the test gas must be at a level to give a response of approximately 80% of full scale. The concentration must be known to an accuracy of ± 2% in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder must be preconditioned for 24 hours at a temperature of 25℃ ±5℃.

8.2.4 The test gases to be used and the recommended relative response factor ranges are as follows:

– Methane and purified synthetic air $1.00 \leq r_h \leq 1.15$

– Propylene and purified synthetic air $0.90 \leq r_h \leq 1.1$

– Toluene and purified synthetic air $0.90 \leq r_h \leq 1.1$

These values are relative to a r_h of 1 for propane and purified synthetic air.

8.3 Oxygen interference check

8.3.1 The oxygen interference check is to be determined when introducing an analyser into service and after major service intervals.

8.3.2 A range is to be chosen where the oxygen interference check gases will fall in the upper 50%. The test is to be conducted with the oven temperature set as required. The oxygen interference gases are specified in 2.3.5.

(1) The analyser is to be zeroed.

(2) The analyser is to be spanned with the 21% oxygen blend.

(3) The zero response is to be rechecked. If it has changed more than 0.5% of full scale (FS) steps (1) and (2) are to be repeated.

(4) The 5% and 10% oxygen interference check gases are to be introduced.

(5) The zero response is to be rechecked. If it has changed more than ±1% of full scale, the test is to be repeated.

(6) The oxygen interference (%O_{2I}) is to be calculated for each mixture in step (4) as follows:

$$O_{2\mathrm{I}} = \frac{(B - B_{\mathrm{R}})}{B}.100 \quad (2)$$

$$B_{\mathrm{R}} = \frac{A}{A_1} \times B_1 \quad (3)$$

where:

$O_{2\mathrm{I}}$ = oxygen interference of HC analyzer, %;

A = hydrocarbon concentration in ppmC (microlitres per litre) of the span gas used in (2);

B = hydrocarbon concentration (ppmC) of the oxygen interference check gases used in (4);

B_{R} = analyser response used in (4);

A_1 = percentage of full scale analyser response due to A, in %;

B_1 = percentage of full scale analyser response due to B, in %;

(7) The % of oxygen interference (%O_{2I}) is to be less than ±3.0% for all required oxygen interference check gases prior to testing.

(8) If the oxygen interference is greater than ±3.0%, the air flow above and below the manufacturer's specifications are to be incrementally adjusted, repeating 8.1 for each flow.

(9) If the oxygen interference is greater than ± 3.0% after adjusting the air flow, the fuel flow and thereafter the sample flow are to be varied, repeating 8.1 for each new setting.

(10) If the oxygen interference is still greater than ±3.0%, the analyser, (H)FID fuel, or burner air is to be repaired or replaced prior to testing. 8.3.2 is then to be repeated with the repaired or replaced equipment or gases.

9 Interference effects with CO, CO_2, NOx and O_2 analysers

Gases other than the one being analysed can interfere with the reading in several ways. Positive interference occurs in NDIR and PMD instruments where the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks in 9.1 and 9.2 are to be performed prior to an analyser's initial use and after major service intervals, but at least once per year.

9.1 CO analyser interference check

Water and CO_2 can interfere with the CO analyser performance. Therefore, a CO_2 span gas having a concentration of 80% to 100% of full scale of the maximum operating range used during testing is to be bubbled through water at room temperature and the analyser response recorded. The analyzer response must not be more than 1% of full scale for ranges equal to or above 300 ppm or more than 3 ppm for ranges below 300 ppm.

9.2 NO_x analyser quench checks

The two gases of concern for CLD (and HCLD) analysers are CO_2 and water vapour. Quench responses to these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.

9.2.1 CO_2 quench check

9.2.1.1 A CO_2 span gas having a concentration of 80% to 100% of full scale of the maximum operating range is to be passed through the NDIR analyser and the CO_2 value recorded as A. It is then to be diluted approximately 50% with NO span gas and passed through the NDIR and (H)CLD, with the CO_2 and NO values recorded as B and C, respectively. The CO_2 is then to be shut off and only the NO span gas be passed through the (H)CLD and the NO value recorded as *D*.

9.2.1.2 The quench is to be calculated as follows and is not to exceed 2% of full scale:

$$E_{CO_2} = (1 - \frac{C \cdot A}{D \cdot A - D \cdot B}) \cdot 100$$

where: A = is the undiluted CO_2 concentration measured with NDIR in percentage by volume;
B = is the diluted CO_2 concentration measured with NDIR in percentage by volume;
C = is the diluted NO concentration measured with (H)CLD in ppm; and
D = is the undiluted NO concentration measured with (H)CLD in ppm.

9.2.1.3 Alternative methods of diluting and quantifying of CO_2 and NO span gas values such as dynamic mixing/blending, can be used.

9.2.2 Water quench check

9.2.2.1 This check applies to wet gas concentration measurements only. Calculation of water quench must consider dilution of the NO span gas with water vapour and scaling of water vapour concentration of the mixture to that expected during testing.

9.2.2.2 A NO span gas having a concentration of 80% to 100% of full scale of the normal operating range is to be passed through the HCLD and the NO value recorded as *D*. The NO span gas is then to be bubbled through water at a temperature of 25℃ ±5℃ and pass through the HCLD and record the NO value as C. The water temperature is to be determined and recorded as F. The mixture's saturation vapour pressure that corresponds to the bubbler water temperature (F) is to be determined and recorded as *G*. The water vapour concentration (*H* in %) of the mixture is to be calculated as follows:

$$H = 100 \cdot (\frac{G}{p_b}) \quad (5)$$

The expected diluted NO span gas (in water vapour) concentration (D_e) is to be calculated as follows:

$$D_e = D \cdot (1 - \frac{H}{100}) \quad (6)$$

For diesel engine exhaust, the maximum exhaust water concentration H_m (in %) expected during testing is to be estimated, under the assumption of a fuel atom *H*/*C* ratio of 1.8/1, from the maximum CO_2 concentration *A* (measured according to 9.2.1) in the exhaust gas as follows:

$$H_m = 0.9 \cdot A$$

(7)

9.2.2.3 The water quench is to be calculated as follows and is not to exceed 3%:

9.2.2.3 The water quench is to be calculated as follows and is not to exceed 3%:

$$E_{H_2O} = 100 \cdot \frac{D_e - C}{D_e} \cdot \frac{H_m}{H} \quad (8)$$

where: D_e = is the expected diluted NO concentration in ppm;
C = is the diluted NO concentration in ppm;
H_m = is the maximum water vapour concentration in %; and
H = is the actual water vapour concentration in %.

Note: It is important that the NO span gas contains minimal NO_2 concentration for this check, since absorption of NO_2 in water has not been accounted for in the quench calculations.

9.3 O_2 analyser interference

9.3.1 Instrument response of a PMD analyser caused by gases other than oxygen is comparatively slight. The oxygen equivalents (for pure oxygen this value is 100%) of the common exhaust gas constituents are shown in Table 6.

Oxygen equivalents **Table 6**

Gas	O_2 equivalent %
Carbon dioxide (CO_2)	-0.623
Carbon monoxide (CO)	-0.354
Nitric oxide (NO)	+44.4
Nitrogen dioxide (NO_2)	+28.7
Water (H_2O)	-0.381

9.3.2 The observed oxygen concentration is to be corrected by the following formula:

$$c_{O_2,\text{corrected}} = c_{O_2} - E_{O_2,x} \quad (9)$$

$$E_{O_2,x} = EQ_{O_2,x} \cdot c_x \quad (10)$$

where: $c_{O_2,\text{corrected}}$ is the corrected oxygen concentration, in %;

c_{O_2} is the oxygen concentration actually observed through analyser, in %;

$E_{O_2,x}$ is the offset of oxygen analyser caused by gas x other than oxygen, in %;

$EQ_{O_2,x}$ is the O_2 equivalent of gas x other than oxygen, to be provided by manufacturer of analyser or the O_2 equivalent given in table 6 may be taken for reference;

c_x is the concentration of gas x other than oxygen, in %.

9.3.3 For ZRDO and ECS analysers, instrument interference caused by gases other than oxygen is to be compensated in accordance with the manufacturer's recommendations and with good engineering practice. Electrochemical sensors are to be compensated for CO_2 and NO_x interference.

Appendix 9 Parent Engine test report and test data

(Refer to 5.9 and 3.4.9.1(5) of the Guidelines)

Section 1 – Parent Engine test report – see 5.9 of the Guidelines

Emissions Test Report No. **Sheet 1/5**

Engine					
manufacturer					
engine type					
family or group identification					
serial number					
rated speed	rpm				
rated power	kW				
intermediate speed	rpm				
Maximum torque at intermediate speed	Nm				
Static injection or ignition timing	(deg)CA BTDC				
Electronic injection or ignition control	□Yes □No				
Variable injection or ignition control	□Yes □No				
Variable turbocharger geometry	□Yes □No				
Bore	mm				
Stroke	mm				
Nominal compression ratio					
Mean effective pressure, at rated power	kPa				
Maximum cylinder pressure, at rated power	kPa				
Cylinder number and configuration	Number: □V □In-line				
Auxiliaries					
Specified Ambient Conditions					
Maximum seawater temperature	℃				
Maximum charge air temperature, if applicable	℃				
Cooling system spec. intermediate cooler	□Yes □No				
Cooling system spec. charge air stages					
Low/high temperature cooling system set points	/ ℃				
Maximum inlet depression	kPa				
Maximum exhaust back pressure	kPa				
Fuel oil specification					
Fuel oil temperature	℃				
Emission Test Results					
Cycle					
NOx g/kwh					
Test identification					
Date/time					
Test site/bench					
Test number					
Surveyor					
Date and place of report					
signature					

Emissions Test Report No. **Sheet 2/5**

Engine Family Information/Group Information (Common specification)			
Combustion Cycle	□2 stroke □4 stroke		
Cooling medium	□air □water		
Cylinder configuration	Required to be written, only if exhaust cleaning devices are applied		
Method of aspiration	□pressure charged □Natural aspired		
Fuel type to be used on board	□distillate □distillate or heavy fuel □dual fuel □gas fuel		
Ignition methods	□compression ignition □ignition by pilot injection □ignition by spark plug or other external ignition device		
Combustion chamber	□Open chamber □divided chamber		
Valve port configuration	□Cylinder □cylinder wall		
Valve port size and number			
Fuel system type			
Miscellaneous Features			
Exhaust gas recirculation	□Yes □No		
Water injection/emulsion	□Yes □No		
Air injection	□Yes □No		
Charge cooling system	□Yes □No		
Exhaust after-treatment	□Yes □No		
Exhaust after-treatment type			
Dual fuel	□Yes □No		
Engine Family/Group Information (selection of parent engine for test bed test)			
Family/Group Identification			
Method of pressure charging			
Charge air cooling system			
Criteria of the selection (specify)	Highest NOx emission value		
Number of cylinder			
Max. rated power per cylinder			
Rated speed			
Injection or ignition timing(range)			
Max. fuel parent engine			
Selected parent engine			Parent
Test cycle(s)			

Exhaust pipe	
Diameter	mm
Length	m
Insulation	□Yes □No
Probe location	

Measurement equipment

	Manufacturer	Model	Measurement ranges	Calibration	
				Span gas conc.	Deviation of calibration
Analyser					
NOx Analyser			ppm		%
CO Analyser			ppm		%
CO_2 Analyser			%		%
O_2 Analyser			%		%
HC Analyser			ppmC		%
Speed			rpm		%
Torque			Nm		%
Power(if applicable)			kW		%
Fuel flow					%
Air flow					%
Exhaust flow					%
Temperatures					
Charge air coolant inlet			℃		℃
Exhaust gas			℃		℃
Inlet air			℃		℃
Charge air			℃		℃
Fuel			℃		℃
Pressures					
Exhaust gas			kPa		%
Charge air			kPa		%
Atmospheric			kPa		%
Vapour pressure					
Intake air			kPa		%
humidity					
Intake air			%		%

Liquid Fuel Characteristics

Fuel Type				
Fuel properties:			**Fuel elemental analysis:**	
Density	ISO3675	kg/m^3	Carbon	% m/m
Viscosity	ISO3104	mm^2/s	Hydrogen	% m/m
Water	ISO3733	% V/V	Nitrogen	% m/m
			Oxygen	% m/m
			Sulphur	% m/m
			LHV/HU	MJ/kg

Gas fuel characteristics

Fuel Type				
Fuel properties:			**Fuel elemental analysis:**	
Methane number	EN16726: 2015		Carbon	% m/m
Lower heating value		MJ/kg	Hydrogen	% m/m
Boiling point		°C	Nitrogen	% m/m
Density at boiling point		kg/m³	Oxygen	% m/m
Pressure at boiling point		bar (abs)	Sulphur	% m/m
			Methane, CH4	mol%
			Ethane, C2H6	mol%
			Propane, C3H8	mol%
			Isobutane, iC4H10	mol%
			N-Butane, nC4H10	mol%
			Pentane, C5H12	mol%
			C6+	mol%
			CO2	mol%

Emissions Test Report No. .... Ambient and Gaseous Emissions Data **Sheet 4/5**

Mode	1	2	3	4	5	6	7	8
Power/Torque %								
Speed %								
Time at beginning of mode								

Ambient Data								
Atmospheric pressure kPa								
Intake air temperature ℃								
Intake air humidity g/kg								
Relative humidity (RH) of intake air* %								
Air temperature at RH sensor* ℃								
Dry bulb temperature of intake air* ℃								
Wet bulb temperature of intake air* ℃								
Test condition factor(fa)								

Gaseous Emission Data								
NOx Concentration dry/wet ppm								
CO Concentration dry/wet ppm								
CO_2 Concentration dry/wet %								
O_2 Concentration dry/wet %								
HC Concentration dry/wet ppmC								
NOx humidity correction factor, k_{hd}								
Dry/wet correction factor, k_{wr}								
NOx mass flow kg/h								
CO mass flow kg/h								
CO_2 mass flow kg/h								
O_2 mass flow kg/h								
HC mass flow kg/h								
NOx specific kg/kWh								

* As applicable.

Emissions Test Report No. .... Engine Test Data **Sheet 5/5**

Mode	1	2	3	4	5	6	7	8
Power/Torque %								
Speed %								
Time at beginning of mode								

Engine Data								
Speed rpm								
Auxiliary power kW								
Dynamometer setting kW								
Power kW								
Mean effective pressure kPa								
Fuel rack/gas admission duration** mm/sec								
Uncorrected spec. fuel consumption g/kWh								
Fuel mass flow kg/h								
Air mass flow kg/h								
Exhaust mass flow (q_{mew}) kg/h								
Exhaust temperature ℃								
Exhaust back pressure kPa								
Charge air coolant temperature in ℃								
Charge air coolant temperature out ℃								
Charge air temperature ℃								
Charge air reference temperature ℃								
Charge air pressure kPa								
Fuel oil temperature ℃								

* As applicable.

**Only for engines to be tested with gas fuel.

Section 2 – Parent Engine test data to be included in the Technical File – see 3.4.9.1(5) of the Guidelines

Engine Family / Engine Group Reference		
Parent Engine		
Model/Type		
Nominated rated power	kW	
Nominated rated speed	rpm	

Parent Engine test liquid fuel		
Reference fuel designation		
ISO 8217: 2005 grade		
Carbon	% m/m	
Hydrogen	% m/m	
Sulphur	% m/m	
Nitrogen	% m/m	
Oxygen	% m/m	
Water	% V/V	

Parent Engine test gas fuel		
ISO 8178-5:2008		
Carbon	% m/m	
Hydrogen	% m/m	
Sulphur	% m/m	
Nitrogen	% m/m	
Oxygen	% m/m	
Methane, CH4	mol%	
Ethane, C2H6	mol%	
Propane, C3H8	mol%	
Isobutane, iC4H10	mol%	
N-Butane, nC4H10	mol%	
Pentane, C5H12	mol%	
C6+	mol%	
CO_2	mol%	

Measured data (Parent Engine)									
Power/Torque	%								

Speed	%								
Mode point		1	2	3	4	5	6	7	8
Engine Performance									
Power	kW								
Speed	rpm								
Fuel flow	kg/h								
Intake air flow (wet/dry)	kg/h								
Exhaust gas flow	kg/h								
Intake air temperature	℃								
Charge air temperature	℃								
Charge air reference temperature	℃								
Charge air pressure	kPa								
Additional parameter(s) used for emission corrections (specify)									
Ambient conditions									
Atmospheric pressure	kPa								
Relative humidity (RH) of intake air	%								
Air temperature at RH sensor*	℃								
Dry bulb temperature of intake air*	℃								
Wet bulb temperature of intake air*	℃								
Absolute humidity of intake air*	g/kg								
Emission concentrations									
NOx wet/dry	ppm								
CO_2	%								
O_2 wet/dry	%								
CO	ppm								
HC	ppmC								
Calculated data (Parent Engine)									
Intake air humidity	g/kg								
Charge air humidity	g/kg								
Test condition parameter, f_a									
Dry/wet correction factor, k_{wr}									
NOx humidity correction factor, k_h									
Exhaust gas flow rate	kg/h								
NOx emission flow rate	kg/h								
Additional emission correction factor(s) (specify)	g/kWh								
	g/kWh								
NOx emission	g/kWh								

Test cycle					
Emission value	g/kWh				

* As applicable.

Appendix 10 Calculation of exhaust gas mass flow (carbon-balance method)

(*Refer to chapter 5 of the Guidelines*)

1 Introduction

1.1 This appendix addresses the calculation of the exhaust gas mass flow based on exhaust gas concentration measurement, and on the knowledge of fuel consumption. Symbols and descriptions of terms and variables used in the formulae for the carbon-balance measurement method are summarized in appendix 13 of the Guidelines.

1.2 Except as otherwise specified, all results of calculations required by this appendix are to be reported in the engine's test report in accordance with 5.9 of the Guidelines.

2 Carbon balance method, 1-step calculation procedure

2.1 This method involves exhaust mass calculation from fuel consumption, fuel composition and exhaust gas concentrations.

2.2 Exhaust gas mass flow rate on wet basis:

$$q_{\mathrm{mew}} = q_{\mathrm{mf}} \cdot \left(\left(\frac{\dfrac{w_{\mathrm{BET}} \cdot w_{\mathrm{BET}} \cdot 1.4}{\left(\dfrac{1.4 \cdot w_{\mathrm{BET}}}{f_{\mathrm{c}}} + w_{\mathrm{ALF}} \cdot 0.08936 - 1\right) \cdot \dfrac{1}{1.293} + f_{\mathrm{fd}}}}{f_{\mathrm{c}} \cdot f_{\mathrm{c}}} + w_{\mathrm{ALF}} \cdot 0.08936 - 1 \right) \cdot \left(1 + \frac{H_{\mathrm{a}}}{1000}\right) + 1 \right) \quad (1)$$

with:

f_{fd} according to equation (2), f_{c} according to equation (3).

*H*a is the absolute humidity of intake air, in gram water per kg dry air, however if $Ha \geq HSC$, then *H*SC is to be used in place of *H*a in formula (1).

Note: H_a may be derived from relative humidity measurement, dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.3 The fuel specific constant f_{fd} for the dry exhaust is to be calculated by adding up the additional volumes of the combustion of the fuel elements:

$$f_{\mathrm{fd}} = -0.055593 \cdot w_{\mathrm{ALF}} + 0.008002 \cdot w_{\mathrm{DEL}} + 0.0070046 \cdot w_{\mathrm{EPS}} \quad (2)$$

2.4 Carbon factor *fc* according to equation (3):

$$f_{\mathrm{c}} = (c_{\mathrm{CO_2d}} - c_{\mathrm{CO_2ad}}) \cdot 0.5441 + \frac{c_{\mathrm{COd}}}{18522} + \frac{c_{\mathrm{HCw}}}{17355} \quad (3)$$

with

c_{CO2d} = dry CO2 concentration in the raw exhaust, in %;
c_{CO2ad} = dry CO2 concentration in the ambient air, % = 0.03%;
c_{COd} = dry CO concentration in the raw exhaust, in ppm;
c_{HCw} = wet HC concentration in the raw exhaust, in ppm.

2.5 q_{mf}, W_{ALF}, W_{BET}, W_{DEL}, W_{EPS}, f_{fd} parameters, in formula (1), are to be calculated as follows:

Factors in formula (1)		Formula of factors
q_{mf}	=	$q_{mf\_G} + q_{mf\_L}$
W_{ALF}	=	$\dfrac{q_{mf\_G} \times w_{ALF\_G} + q_{mf\_L} \times w_{ALF\_L}}{q_{mf\_G} + q_{mf\_L}}$

W_{BET}	=	$\frac{q_{mf\_G} \times w_{BET\_G} + q_{mf\_L} \times w_{BET\_L}}{q_{mf\_G} + q_{mf\_L}}$
W_{DEL}	=	$\frac{q_{mf\_G} \times w_{DEL\_G} + q_{mf\_L} \times w_{DEL\_L}}{q_{mf\_G} + q_{mf\_L}}$
W_{EPS}	=	$\frac{q_{mf\_G} \times w_{EPS\_G} + q_{mf\_L} \times w_{EPS\_L}}{q_{mf\_G} + q_{mf\_L}}$

Appendix 11 Checklist for an Engine Parameter Check method

1 For some of the parameters listed below, more than one survey possibility exists. In such cases, as approved by the surveyor of ISC, the shipowner, supported by the applicant for engine certification, may choose which method is applicable.

No.	Parameter	Check method
1	Injection timing and ignition timing	① Fuel cam position (individual cam or camshaft if cams are not adjustable): —optional (dependent on design): position of a link between the cam and the pump drive, —optional for sleeve-metered pumps: VIT index and cam position or position of the barrel, or —other sleeve metering device; ② start of delivery for certain fuel rack positions (dynamic pressure measurement); ③ opening of injection valve for certain load points, e.g., using a Hall sensor or acceleration pick-up; ④ load-dependent operating values for charge air pressure, combustion peak pressure, charge air temperature, exhaust gas temperature versus graphs showing the correlation with NO_x. Additionally, it is to be ensured that the compression ratio corresponds to the initial certification value; and ⑤ timing indicator or timing light. *Note*: To assess the actual timing, it is necessary to know the allowable limits for meeting the emission limits or even graphs showing the influence of timing on NO_x, based on the test-bed measurement results.
2	Injection nozzle	① specification and component identification number.
3	Injection pump	① component identification number (specifying plunger and barrel design).
4	Fuel cam	① component identification number (specifying shape); ② start and end of delivery for a certain fuel rack position (dynamic pressure measurement).
5	Injection pressure	① only for common-rail systems: load-dependent pressure in the rail, graph showing correlation with NO_x.
6	Combustion chamber	① component identification numbers for the cylinder head and piston head;
7	Compression ratio	①check for actual clearance; ②check for shims in piston rod or connecting rod;
8	Turbocharger type and build	①model and specification (identification numbers); ②load-dependent charge air pressure, graph showing the correlation with NO_x;
9	Charge air cooler, charge air heater	①model and specification; ②load-dependent charge air temperature corrected to reference conditions, graph showing the correlation with NO_x;
10	Valve timing	① cam position; ② check actual timing;
11	Water injection	① load-dependent water consumption (monitoring);
12	Emulsified fuel	① load-dependent fuel rack position (monitoring); ② load-dependent water consumption (monitoring);
13	Exhaust gas recirculation	① load-dependent mass flow of recirculated exhaust gas (monitoring); ② CO_2 concentration in the mixture of fresh air and recirculated exhaust gas, i.e. in the "scavenge air" (monitoring); ③ O_2 concentration in the "scavenge air" (monitoring);
14	Selective catalytic reduction	① load-dependent mass flow of reducing agent (monitoring) and additional periodical spot checks on NO_x concentration after SCR (for assessment: graph showing influence on NO_x).

2 For engines with selective catalytic reduction (SCR) without feedback control, optional NO_x measurement (periodical spot checks or monitoring) is useful to show that the SCR efficiency still corresponds to the state at the time of certification regardless of whether the ambient conditions or the fuel quality led to different raw emissions.

Appendix 12 Implementation of the Direct Measurement and Monitoring method
(*Refer to 6.4 of the Guidelines*)

1 Electrical equipment: materials and design

1.1 Electrical equipment is to be constructed of durable, flame-retardant, moisture resistant materials, which are not subject to deterioration in the installed environment and at the temperatures to which the equipment is likely to be exposed.

1.2 Electrical equipment is to be designed such that current carrying parts with potential to earth are protected against accidental contact.

2 Analysing equipment

2.1 Analysers

2.1.1 The exhaust gases are to be analysed with the following instruments. For non-linear analysers, the use of linearizing circuits is permitted. Other systems or analysers may be accepted, subject to the approval of ISC, provided they yield equivalent results to that of the equipment referenced below:

2.1.1.1 Nitrogen oxides (NO_x) analysis

The nitrogen oxides analyser is to be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type. The exhaust gas sampled for NO_x measurement is to be maintained above its dewpoint temperature until it has passed through the NO_2 to NO converter.

Note: In the case of raw exhaust gas this temperature is to be greater than 60ºC if the engine is fuelled with ISO 8217 DM-grade type fuel and greater than 140ºC if fuelled with ISO 8217 RM-grade type fuel.

2.1.1.2 Carbon dioxide (CO_2) analysis

When required, the carbon dioxide analyser is to be of the non-dispersive infrared (NDIR) absorption type.

2.1.1.3 Carbon monoxide (CO) analysis

When required, the carbon monoxide analyser is to be of the non-dispersive infrared (NDIR) absorption type.

2.1.1.4 Hydrocarbon (HC) analysis

When required, the hydrocarbon analyser is to be of the heated flame ionization detector (HFID) type. The exhaust gas sampled for HC measurement is to be maintained at 190℃ ±10ºC from the sample point to the detector. Optionally, for gas-fuelled engines (without liquid pilot injection), the hydrocarbon analyser may be of the non-heated flame ionization detector (FID) type.

2.1.1.5 Oxygen (O_2) analysis

When required, the oxygen analyser is to be of the paramagnetic detector (PMD), zirconium dioxide (ZRDO) or electrochemical sensor (ECS) type. ZRDO is not to be used for dual fuel or gas-fuelled engines.

2.2 Analyser specifications

2.2.1 The analyser specifications are to be consistent with 1.6, 1.7, 1.8, 1.9 and 1.10 of appendix 7 of the Guidelines.

2.2.2 The analyser range is to be such that the measured emission value is within 15% – 100% of the range used.

2.2.3 The analysing equipment is to be installed and maintained in accordance with manufacturers' recommendations in order to meet the requirements of 1.7, 1.8, 1.9, and 1.10 of appendix 7 of the Guidelines and sections 7 and 9 of appendix 8 of the Guidelines.

3 Pure and calibration gases

3.1 Pure and calibration gases, as required, are to comply with 2.2 and 2.3 of appendix 8 of the Guidelines. Declared concentrations are to be traceable to national and/or international standards. Calibration gases are to be in accordance with the analysing equipment manufacturers' recommendations.

3.2 Analyser span gases are to be between 80% – 100% of the analyser scale being spanned.

4 Gas sampling and transfer system

4.1 The exhaust gas sample is to be representative of the average exhaust emission from all the engine's cylinders. The gas sampling system is to comply with 5.8.1 of the Guidelines.

4.2 The exhaust gas sample is to be drawn from a zone within 10% to 90% of the duct diameter.

4.3 In order to facilitate the installation of the sampling probe, an example of a sample point connection flange is given in section 5.

4.4 The exhaust gas sample for NO_x measurement is to be maintained so as to prevent NO_2 loss via water or acid condensation in accordance with analysing equipment manufacturers' recommendations.

4.5 The gas sample is not to be dried by chemical driers.

4.6 The gas sampling system is to be capable of being verified to be free of ingress leakage in accordance with analysing equipment manufacturers' recommendations.

4.7 An additional sample point adjacent to that used is to be provided to facilitate quality control checks on the system.

5 Sample point connection flange

5.1 The following is an example of a general purpose sample point connection flange which is to be sited, as convenient, on the exhaust duct of each engine for which it may be required to demonstrate compliance by means of the Direct Measurement and Monitoring method.

Description	Dimension
Outer diameter	160 mm
Inner diameter	35 mm
Flange thickness	9 mm
Bolt circle diameter 1	130 mm
Bolt circle diameter 2	65 mm
Flange slots	4 holes, each 12 mm diameter, equidistantly placed on each of the above bolt circle diameters. Holes on the two bolt circle diameters to be aligned on same radii. Flange to be slotted, 12 mm wide, between inner and outer bolt circle diameter holes.
Bolts and nuts	4 sets, diameter and length as required.
Flange is to be of steel and be finished with a flat face.	

5.2 The flange is to be fitted to a stub pipe of suitable gauge material aligned with the exhaust duct diameter. The stub pipe is to be no longer than necessary to project beyond the exhaust duct cladding, sufficient to enable access to the far side of the flange. The stub pipe is to be insulated. The stub pipe is to terminate at an accessible position free from nearby obstructions which would interfere with the location or mounting of a sample probe and associated fittings.

5.3 When not in use, the stub pipe is to be closed with a steel blank flange and a gasket of suitable heat resisting material. The sampling flange, and closing blank flange, when not in use, is to be covered with a readily removable and suitable heat resistant material which protects against accidental contact.

6 Selection of load points and revised weighting factors

6.1 As provided for by 6.4.6.3 and 6.4.6.4 of the Guidelines, in the case of the E2, E3 or D2 test cycles, the minimum number of load points are to be such that the combined nominal weighting factors, as given in 2.5 of the Guidelines, are greater than 0.50.

6.2 In accordance with 6.1, for the E2 and E3 test cycles it would be necessary to use the 75% load point plus one or more other load points. In the case of the D2 test cycle, either the 25% or 50% load point is to be used plus either one or more load points such that the combined nominal weighting factor is greater than 0.50.

6.3 The examples in 6.3.1 and 6.3.2 give some of the possible combinations of load points of E2, E3 and D2 which may be used together with the respective revised weighting factors:

6.3.1 E2 and E3 test cycles:

Power	100%	75%	50%	25%
Nominal weighting factor	0.2	0.5	0.15	0.15
Option A	0.29	0.71		
Option B		0.77	0.23	
Option C	0.24	0.59		0.18
Plus other combinations which result in a combined nominal weighting factor greater than 0.50. Hence use of the 100% + 50% + 10% load points would be insufficient.				

6.3.2 D2 test cycle

Power	100%	75%	50%	25%	10%
Nominal weighting factor	0.05	0.25	0.3	0.3	0.1
Option D			0.5	0.5	
Option E		0.45		0.55	
Option F		0.38	0.46		0.15
Option G	0.06	0.28	0.33	0.33	
Plus other combinations which result in a combined nominal weighting factor greater than 0.50. Hence use of the 100% + 50% + 10% load points would be insufficient.					

6.4 In the case of the C1 test cycle, as a minimum, one load point from each of the rated, intermediate and idle speed sections are to be used. The examples below give some of the possible combinations of load points which may be used together with the respective revised weighting factors:

6.4.1 C1 test cycle

Speed	Rated				Intermediate			Idle
Torque	100%	75%	50%	10%	100%	75%	50%	0%
Nominal weighting factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
Option H		0.38			0.25			0.38
Option I				0.29		0.29		0.43
Option J	0.27	0.27					0.18	0.27
Option K	0.19	0.19	0.19	0.13		0.13		0.19
Plus other combinations incorporating at least one load point at each of rated, intermediate and idle speeds.								

6.5 Examples of calculation of revised weighting factors:

(1) For a given load point, revised weighting factors are to be calculated as follows:

y% load = nominal weighting factor at load *y* ·(1/(sum of the load factors for load points where data was acquired))

(2) For Option A:

75% load: revised value is calculated as: 0.5 ·(1/(0.5 + 0.2)) = 0.71
100% load: revised value is calculated as: 0.2 ·(1/(0.5 + 0.2)) = 0.29

(3) For Option F:

75% load: revised value is calculated as: 0.25 ·(1/(0.25 + 0.3 + 0.1)) = 0.38

(4) The revised weighting factors are shown to two decimal places. However, the values to be applied to equation 18 are to be to the full precision. Hence in the Option F case above the revised weighting factor is shown as 0.38 although the actual calculated value is 0.384615. Consequently, in these examples of revised weighting factors the summation of the values shown (to two decimal places) may not sum to 1.00 due to rounding.

7 Determination of power set point stability

7.1 To determine set point stability, the power coefficient of variance is to be calculated over a 10-minute interval, and the sampling rate is to be at least 1-Hz. The result is to be less than or equal to five per cent (5%).

7.2 The formulae for calculating the coefficient of variance are as follows:

$$Ave = \frac{1}{N}\sum_{j=1}^{N} x_j$$

$$S.D. = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - Ave)^2}$$

$$C.O.V. = \frac{S.D.}{Ave} \cdot 100 \le 5\%$$

where:

%C.O.V. — power coefficient of variance, in %;
S.D. s — tandard deviation;
Ave — Average;
N — total number of data points sampled;
x_i, x_j — i^{th}, j^{th} value of power data point, in kW;
i — index variable in standard deviation formula;
j — index variable in average formula.

Appendix 13 Abbreviations, Subscripts and Symbols

Tables 1, 2, 3 and 4 below summarize the abbreviations, subscripts and symbols used throughout the Guidelines, including specifications for the analytical instruments in appendix 7, calibration requirements for the analytic instruments contained in appendix 8, the formulae for calculation of gas mass flow as contained in chapter 5 and appendix 10 of the Guidelines and the symbols used in respect of data for onboard verification surveys in chapter 6.

1. Table 1: symbols used to represent the chemical components of marine diesel engine gas emissions and calibration and span gases addressed throughout the Guidelines;
2. Table 2: abbreviations for the analysers used in the measurement of gas emissions from marine diesel engines as specified in appendix 7 of the Guidelines;
3. Table 3: symbols and subscripts of terms and variables used in chapter 5, chapter 6, appendix 8 and appendix 10 of the Guidelines; and
4. Table 4: symbols for fuel composition used in chapter 5 and chapter 6 and appendix 10 of this Code.

Table 1
Symbols and abbreviations for the chemical components

Symbol	Definition
CH_4	Methane
C_3H_8	Propane
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydrocarbons
H_2O	Water
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_2	Oxygen

Table 2
Abbreviations for Analysers for measurement of marine diesel engine gaseous emissions
(refer to appendix 7 of the Guidelines)

CLD	Chemiluminescent detector
ECS	Electrochemical sensor
HCLD	Heated chemiluminescent detector
(H)FID	(Heated) flame ionization detector
NDIR	Non-dispersive infrared analyser
PMD	Paramagnetic detector
ZRDO	Zirconium dioxide sensor

Table 3
Symbols and subscripts for terms and variables
(refer to chapter 5, chapter 6, appendix 8 and appendix 10 of the Guidelines)

Symbol	Term	Unit
A/F_{st}	Stoichiometric air to fuel ratio	1
c_x	Concentration in the exhaust (with suffix of the component nominating, *d* = dry or *w* = wet)	ppm/% (V/V)
E_{CO_2}	CO_2 quench of NO_x analyser	%
E_{H_2O}	Water quench of NO_x analyser	%
E_{NOx}	Efficiency of NO_x converter	%
E_{O_2}	Interference offset of oxygen analyser caused by gases other than oxygen	%
λ	Excess air factor: kg dry air/(kg fuel ·A/Fst)	1
f_a	Test condition parameter	1
f_c	Carbon factor	1
f_{fd}	Fuel specific factor for exhaust flow calculation on dry basis	1
f_{fw}	Fuel specific factor for exhaust flow calculation on wet basis	1
H_a	Absolute humidity of the intake air (g water / kg dry air)	g/kg
H_{SC}	Humidity of the charge air	g/kg
i	Subscript denoting an individual mode	1
k_{hd}	Humidity correction factor for NO_x for diesel engines	1
k_{wa}	Dry to wet correction factor for the intake air	1
k_{wr}	Dry to wet correction factor for the raw exhaust gas	1
n_d	Engine speed	rpm
n_{turb}	Turbocharger speed	rpm
O_{2I}	HC analyser percentage oxygen interference	%
p_a	Saturation vapour pressure of the engine intake air determined using a temperature value for the intake air measured at the same physical location as the measurements for p_b and R_a	kPa
p_b	Total barometric pressure	kPa
p_C	Charge air pressure	kPa
p_r	Water vapour pressure after cooling bath of the analysis system	kPa
p_s	Dry atmospheric pressure calculated by the following formula: $p_s = p_b - R_a \cdot p_a / 100$	kPa
p_{SC}	Saturation vapour pressure of the charge air	kPa
P	Uncorrected brake power	kW
P_{aux}	Declared total power absorbed by auxiliaries fitted for the test and not required by ISO 14396	kW
P_m	Maximum measured or declared power at the test engine speed under test conditions	kW
q_{mad}	Intake air mass flow rate on dry basis	kg/h
q_{maw}	Intake air mass flow rate on wet basis	kg/h
q_{mew}	Exhaust gas mass flow rate on wet basis	
q_{mf}	Fuel mass flow rate	kg/h
q_{mgas}	Emission mass flow rate of individual gas	
R_a	Relative humidity of the intake air	

Symbol	Term	Unit
r_h	Hydrocarbon response factor	1
ρ	Density	
s	Fuel rack position	
T_a	Intake air temperature determined at the engine intake	
T_{caclin}	Charge air cooler, coolant inlet temperature	
$T_{caclout}$	Charge air cooler, coolant outlet temperature	
T_{Exh}	Exhaust gas temperature	℃
T_{Fuel}	Fuel oil temperature	
T_{Sea}	Seawater temperature	
T_{SC}	Charge air temperature	
T_{SCRef}	Charge air reference temperature	K
u	Ratio of exhaust component and exhaust gas densities	
W_F	Weighting factor	

Table 4
Symbols for fuel composition

Symbol	Definition	Unit
W_{ALF}^{*}	H content of fuel	% m/m
W_{BET}^{*}	C content of fuel	% m/m
W_{GAM}	S content of fuel	% m/m
W_{DEL}^{*}	N content of fuel	% m/m
W_{EPS}^{*}	O content of fuel	% m/m
α	molar ratio (H/C)	1

* Subscript “_G” denotes gas-fuel fraction; “_L” denotes liquid-fuel fraction.

Appendix 14 2017 Guidelines Addressing Additional Aspects of the NOx Technical Code 2008 with regard to Particular Requirements related to Marine Diesel Engines Fitted with Selective Catalytic Reduction (SCR) Systems

1 INTRODUCTION

1.1 The use of NOx-reducing devices is envisaged in section 2.2.5 of the NOx Technical Code 2008 (NTC 2008) and a Selective Catalytic Reduction (SCR) system is one of such devices.

1.2 The NTC 2008 contains two ways for pre-certification of engine systems fitted with NOx-reducing devices:

- .1 engine fitted with SCR: approval in accordance with paragraph 2.2.5.1 and test in accordance with chapter 5 of the NTC 2008; and
- .2 a simplified measurement method in accordance with section 6.3 of the NTC 2008 as regulated in paragraph 2.2.5.2 (Primary failure case) of the Code.

1.3 According to paragraph 2.2.5.1 of the NTC 2008, where a NOx-reducing device is to be included within the EIAPP certification, it must be recognized as a component of the engine, and its presence shall be recorded in the engine's Technical File.

1.4 These Guidelines is to taken into account when certifying engines fitted with SCR.

2 GENERAL

2.1 Purpose

The purpose of these Guidelines is to provide guidance in addition to the requirements of the NTC 2008 for design, testing, surveys and certification of marine diesel engines fitted with an SCR system to ensure its compliance with the requirements of regulation 13 of MARPOL Annex VI.

2.2 Application

These Guidelines apply to marine diesel engines fitted with SCR for compliance with regulation 13 of MARPOL Annex VI.

2.3 Definitions

Unless provided otherwise, the terms in these Guidelines have the same meaning as the terms defined in regulation 2 of MARPOL Annex VI and in section 1.3 of the NTC 2008.

2.3.1 "Engine system fitted with SCR" means a system consisting of a marine diesel engine, an SCR chamber and a reductant injection system. When a control device on NOx-reducing performance is provided, it is also regarded as a part of the system.

2.3.2 "Catalyst block" means a block of certain dimension through which exhaust gas passes and which contains catalyst composition on its inside surface to reduce NOx from exhaust gas.

2.3.3 "SCR chamber" means an integrated unit, which contains the catalyst block(s), and into which flows exhaust gas and reductant.

2.3.4 "Reductant injection system" means a system, which consists of the pump(s) to supply reductant to the nozzle(s), the nozzle(s) spraying reductant into the exhaust gas stream and control device(s) of the spray.

2.3.5 "AV (area velocity) value" means a value of the exhaust gas flow rate passing through the catalyst blocks (m3/h) per total active surface area of the catalyst blocks in the SCR chamber (m2). Therefore, unit of AV value is (m/h). The exhaust gas flow volume is the volume defined at 0°C and 101.3 kPa.

2.3.6 "SV (space velocity) value" means a value of the exhaust gas flow rate passing through the catalyst block(s) (m3/h) per total volume of the catalyst block(s) in the SCR chamber (m3). Therefore, unit of SV value is (1/h). The exhaust gas flow volume is the volume defined at 0°C and 101.3 kPa.

2.3.7 "Total volume of the catalyst block" means the volume (m3) based on outer dimensions of the catalyst block.

2.3.9 "LV (linear velocity) value" means a value of the exhaust gas flow rate passing through the catalyst blocks (m3/h) per catalyst block's section (m2) in a normal direction of exhaust gas flow. Therefore, unit of LV value is (m/h). The exhaust gas flow volume is the volume defined at 0°C and 101.3 kPa.

2.3.9 "Block section" means the cross-sectional area (m2) of the catalyst block based on the outer dimensions.

2.3.10 "NOx reduction rate η" means a value deriving from the following formula. Unit of is (%):

$$\eta = \frac{(c_{inlet} - c_{outlet})}{c_{inlet}} \cdot 100$$

Where: c_{inlet} is NOx concentration (ppm) as measured at the inlet of the SCR chamber;
c_{outlet} is NOx concentration (ppm) as measured at the outlet of the SCR chamber.

2.3.11 "Catalyst block casing or frame" means a casing or frame of an assembly (module) of several catalyst blocks.

3 PRE-CERTIFICATION PROCEDURE

3.1 General

3.1.1 Engine systems fitted with SCR should be certified in accordance with chapter 2 of the NTC 2008. The procedures provided by Scheme A or Scheme B of these Guidelines should be applied.

3.1.2 The applicant for certification should be the entity responsible for the complete engine system fitted with SCR.

3.1.3 The applicant should supply all necessary documentation, including the Technical File for the complete system, a description of the required on board NOx verification procedure and, where applicable, the description of the confirmation test procedure.

3.2 Technical File and on board NOx verification procedures

3.2.1 In addition to the information supplied in paragraph 3.1.3 of these Guidelines and items in section 2.4 of the NTC 2008, engine systems fitted with SCR should include the following information in Technical File:

.1 reductant: component/type and concentration;

.2 reductant injection system including critical dimensions and supply volume;

.3 design features of SCR specific components in the exhaust duct from the engine exhaust manifold to the SCR chamber. The design features are to be specified by the applicant and may include, but are not limited to:

  .1 any restrictions specified by the applicant relating to exhaust duct configuration/design, including the position and number of bends in exhaust duct along with orientation and geometry, exhaust duct changes of diameter and arrangements fitted to manipulate exhaust flow, where applicable;

  .2 minimum distance between reductant injection point(s) and SCR chamber;

  .3 position of reductant injection equipment within duct and the direction of reductant injection, e.g. counter flow or parallel flow;

  .4 reductant mixing arrangements;

  .5 reductant lances, nozzles, atomizing arrangement;

  .6 inlet plenum design, top entry or bottom entry;

  .7 where an SCR by-pass arrangement is stipulated by the applicant, the control specifications, identification of the by-pass valve and its control device; and

  .8 where an integrated reductant injection and SCR chamber arrangement is supplied as a packaged item to be fitted into an exhaust duct, the parameters of such a unit which may affect NOx emissions;

.4 catalyst block specification and arrangement in the SCR chamber. The details of the catalyst block specification and the arrangement of catalyst blocks within the SCR chamber may include, but are not limited to:

  .1 installation of blocks within the SCR chamber, including the number of blocks, number of layers and the SCR chamber casing and frame to prevent exhaust gas slip;

  .2 catalyst block geometry;

  .3 limiting characteristics such as CPSI (cells per square inch) and ranges for physical parameters such as the space velocity (SV), area velocity (AV) and linear velocity (LV), or a part number or specification number specified by the applicant on the catalyst block;

  .4 catalyst material: this may be identified by means of a part number or specification number. The means to ensure a correct catalyst block installed on board against the

Technical File, where a part number or specification number specified by the applicant on the catalyst block casing or frame is acceptable;

.5 arrangement of soot blowing equipment;

.6 inspection and access arrangements. The inspection of the SCR chamber should be limited to ensuring that the correct catalyst blocks are fitted during assembly of the SCR and the inspection of spare catalyst blocks can be accepted to demonstrate compliance at surveys other than at the initial assembly of the SCR; and

.7 any baffle plates or other devices installed within the SCR chamber for exhaust gas and reductant flow distribution;

.5 inlet parameters including allowable exhaust gas temperature (maximum and minimum) at the inlet of the SCR chamber;

.6 cross-unit parameters: allowable pressure loss (Δp) between inlet and outlet of SCR chamber and in the exhaust duct caused by SCR components. Where there is any element of the SCR system upstream and/or downstream of the SCR chamber which affects the allowable pressure loss, then this allowable pressure loss (Δp) is to be based on the entire SCR system;

.7 aspects related to the fuel oil quality resulting in continued compliance of the engine with the applicable NOx emission limit to assure continued NOx reduction may include, but not be limited to:

.1 the maximum allowable sulphur content of fuel oil which can be combusted, while maintaining compliance; and

.2 guidance on applicable fuel oil composition and fuel oil contaminants under operational conditions;

.8 factors related to the deterioration rate of SCR performance, e.g. exchange condition for SCR catalyst blocks and recommended exchange time of SCR catalyst blocks:

.1 where a feedback or a feed forward reductant control strategy is incorporated with a NOx measurement device, this is acceptable as a means of monitoring catalyst condition/degradation. The exchange criteria of catalyst blocks against the reading of the NOx measurement device is to be specified by the applicant as well as the maintenance, service, and calibration requirements for the NOx measurement device;

.2 where a feed forward reductant control strategy is adopted without a NOx measurement device, the application is to provide the details of:

.1 the expected deterioration curve under expected operating conditions or the life of catalyst under expected operating conditions;

.2 factors which can influence catalyst NOx reduction efficiency; and

.3 guidance on how to assess catalyst NOx reduction efficiency based on periodical spot checks or monitoring as specified by the applicant, if applicable; records are to be kept for inspection during annual, intermediate and renewal surveys. The frequency of periodical spot checks is to be defined by the applicant considering the expected deterioration of the catalyst. The frequency for spot-checks should be at least after installation and once every 12 months; and

.3 other strategies on monitoring the catalyst condition/degradation are subject to the approval of ISC;

.9 controlling arrangements and settings of the SCR, e.g. model, specification of control device. This is to include, but not be limited to:

.1 the reductant injection control strategy which may be a feed forward reductant injection control or feedback reductant injection control strategy;

.2 instrumentation and sensors which are part of the SCR control arrangement, as applicable;

.3 crew instructions for allowable adjustment of control parameters including details of how to prevent unauthorized alteration of the system configuration parameters, programmable logic controller (PLC) data, and central processing units (CPU) as applicable;

.4 where a NOx measurement device is used, the following details should be included:

.1 type/model (identification number);

.2 calibration, zero and span check procedures and the periodicity of such checks, if applicable;
.3 calibration gases to be carried on board if applicable; and
.4 maintenance and/or exchange requirements;

.5 where the engine system fitted with SCR has different operating modes (e.g. modes for Tier II and Tier III compliance separately), details of the control philosophy for selecting different modes of operation and recording the mode of operation together with means of changing between modes; and

.6 auxiliary control devices, as mentioned in regulation 13.9 and defined in regulation 2.4 of MARPOL Annex VI, respectively, may be used on engine systems fitted with SCR, covering starting and stopping, low load operation and reversing operation, subject to the approval of ISC;

.10 measures to minimize reductant slip. The maximum reductant slip may be specified by the applicant. Supporting information, including reductant injection rates under certain engine loads, the catalyst temperature or exhaust gas temperature when reductant injection occurs, etc. may be included in order to prevent reductant slip from exceeding the specified maximum level. Reductant slip monitoring in the exhaust duct downstream of the SCR or an equivalent means may be accepted as a means to minimize reductant slip. Alternatively, means of alleviating reductant slip (for example through the use of an ammonia slip catalyst or active catalyst thermal management) may be accepted as a means to minimize reductant slip;

.11 parameter check method as the verification procedure: with regard to the application of the parameter check method, requirements given in paragraph 2.3.6 and guidance given in paragraph 2 of appendix VII of the NTC 2008 should be taken into account in assessing the adequacy of a proposed procedure with analysers meeting or exceeding the requirements of appendix III of the NTC 2008; and

.12 any other parameter(s) specified by the applicant.

3.3 Measures to minimize reductant slip

When SCR uses urea solution, ammonia solution or ammonia gas as reductant, measures to prevent reductant slip should be provided to avoid the supply of an excessive amount of reductant in the system. The reductant injection system should be designed to prevent emissions of any harmful substance from the system.

3.4 Pre-certification procedure

Test and pre-certification of an engine system fitted with SCR should be conducted either by Scheme A (as given in section 5 of these Guidelines), or by Scheme B (as given in sections 6 and 7 of these Guidelines), as appropriate.

3.5 EIAPP certificate

3.5.1 An Engine International Air Pollution Prevention (EIAPP) Certificate (see appendix I of the NTC 2008) should be issued by ISC after approval of the Technical File.

3.5.2 When an applicant chooses Scheme B for pre-certification, the IAPP initial survey should not be completed until the on board initial confirmation test provides compliant results. The applicant remains the responsible entity until final acceptance of the system.

3.5.3 When the engine is to be certified to both Tier II and Tier III, the EIAPP Certificate should be completed for both Tier II and Tier III with a single Technical File covering both Tier modes.

4 FAMILY AND GROUP CONCEPTS FOR ENGINE SYSTEMS FITTED WITH SCR

4.1 The requirements in chapter 4 of the NTC 2008 apply equally to engine systems fitted with SCR.

4.2 The parent engine is to be the engine system fitted with SCR with the highest NOx emission value of the group/family as specified in paragraphs 4.3.9.1 and 4.4.8.1 of the NTC 2008. In cases where there is more than one combined engine/SCR system with the same highest NOx emission value given to two decimal places (cycle value in g/kWh) within an engine family or an engine group, the parent engine is the system with the highest raw NOx value emitted from the engine.

4.3 The parent engine for Tier II compliance is not necessarily the same parent of the combined engine/SCR system for Tier III compliance.

5 TEST PROCEDURES FOR SCHEME A

5.1 General

5.1.1 A test for a combined system of an engine fitted with an SCR in Scheme A is to ensure compliance with the applicable NOx emission limits of MARPOL Annex VI, as required. The test bed measurement procedures of chapter 5 of the NTC 2008 should apply.

5.1.2 Notwithstanding paragraph 5.1.1, the applicant may choose to test the combined system of an engine fitted with an SCR with a by-pass arrangement without that by-pass installed for the purpose of test bed measurement. Any effect to the fluid dynamics or reductant distribution caused by the absence of the by-pass arrangement is to be presented by the applicant.

5.2 Calculation of gaseous emissions

5.2.1 The calculation method in section 5.12 of the NTC 2008 is also applied to engine systems fitted with SCR. No allowance is made for the reductant solution injected into the exhaust gas stream in respect of its effect on exhaust gas mass flow rate calculation (appendix VI) or dry/wet correction factor (equation (11), paragraph 5.12.3.2.2 of the NTC 2008). The NOx correction factor for humidity and temperature (equations (16) or (17), paragraphs 5.12.4.5 and 5.12.4.6, respectively, of the NTC 2008) should not be applied.

5.2.2 For an engine system fitted with SCR, the following parameters should be measured and recorded in the engine test report in accordance with section 5.10 of the NTC 2008:

- .1 injection rate of reductant at each load point (kg/h);
- .2 exhaust gas temperature at the inlet and outlet of the SCR chamber (°C);
- .3 pressure loss (kPa): it is necessary to measure the pressure at inlet and at outlet of the SCR chamber and to calculate pressure loss Δp. It would also be permissible to measure the pressure loss Δp of the SCR chamber with a differential pressure sensor. The allowable Δp limit should be confirmed; and
- .4 other parameter(s) as specified by ISC.

6 TEST PROCEDURES FOR SCHEME B

6.1 General

6.1.1 A test for an engine system fitted with SCR in Scheme B is to ensure that the system complies with the applicable NOx emission limits in MARPOL Annex VI, as required. The test procedures in Scheme B are as follows:

- .1 an engine is tested to obtain the NOx emission value (g/kWh) in accordance with paragraph 6.2.1 of these Guidelines;
- .2 the SCR NOx reduction rate may be calculated by modelling tools, taking into account geometrical reference conditions, chemical NOx conversion models as well as other parameters to be considered;
- .3 for every type of catalytic element, an SCR chamber, not necessarily to full scale, is to be tested in accordance with section 6.3 of these Guidelines in order to generate data for the calculation model as that used in paragraph 6.1.1.2 of these Guidelines;
- .4 the NOx emission from the engine system fitted with SCR, which is calculated in accordance with section 6.4 of these Guidelines using the NOx emission value from the engine and the NOx reduction rate of SCR chamber. At this point the Technical File will be completed and this NOx emission value will be entered into the supplement of the EIAPP certificate; and
- .5 the NOx emission performance of the engine combined with the SCR is verified by a confirmation test in accordance with the procedure in paragraph 7.5 of these Guidelines.

6.1.2 The calculation of gaseous emissions in paragraph 6.1.1.1 of these Guidelines should be undertaken in accordance with paragraph 5.2.1 of these Guidelines.

6.2 Verification test procedures for an engine

6.2.1 The purpose of the test of an engine is to establish the emission values for use in section 6.4 of these Guidelines. These measurements should be in accordance with chapter 5 of the NTC 2008.

6.2.2 Paragraph 5.9.8.1 of the NTC 2008 requires engine conditions to be measured at each mode point, for an engine system. This equally applies in the case of an engine fitted with SCR.

Additionally, exhaust gas temperature at the intended inlet of the SCR chamber should be determined and recorded in the test report as required by section 5.10 of the NTC 2008.

6.3 Test procedures for SCR chambers

6.3.1 **General**

6.3.1.1 The SCR chamber for validation testing may be either a full scale SCR chamber or a scaled version. A SCR chamber should demonstrate the reduction in NOx concentrations (ppm) expected in exhaust gas measured in section 6.2 of these Guidelines. Therefore, NOx reduction rate of the SCR chamber should be determined for each individual mode point. Where undertaken on a scaled version of the SCR chamber the scaling process should be validated to the satisfaction of ISC.

6.3.1.2 The scaling process is to correspond with the modelling tool of paragraph 6.1.1.2 of these Guidelines, and take into account geometrical reference conditions, and chemical NOx conversion models, and other parameters which have influence on NOx conversion rate in the modelling tool. If the scaling process could not be validated satisfactorily by theoretical analysis or calculations taking into consideration the complex conditions in the SCR chamber, such as uniformity of gas speed, reductant, a combined engine and SCR system validation test in accordance with Scheme A should be undertaken.

6.3.1.3 The modelling tool of paragraph 6.1.1.2 of these Guidelines is acceptable for use in other engine groups which operate within the same defined boundary conditions.

6.3.2 **Test conditions at each mode point**

Exhaust gas, catalyst, reductant and an injection system should satisfy the following conditions at each mode point:

.1 Exhaust gas flow

Exhaust gas flow rate for the test should be scaled accordingly to account for the dimension of the catalyst model.

.2 Exhaust gas component

Exhaust gas for the test should either be diesel engine exhaust gas or simulated gas.

Where diesel exhaust gas is used it should correspond, in terms of concentrations, to the exhaust gas in section 6.2 of these Guidelines, in terms of NOx, O2, CO2, H2O and SO2 (±5% of the required concentration for each emission species).

Where simulated gas is used it should correspond, in terms of concentrations, to the exhaust gas in section 6.2 of these Guidelines, in terms of NO, NO2, O2, CO2, H2O and SO2 (±5% of the required concentration for each emission species) balance N2.

An exemption for one or more of the above-mentioned gas species' concentration requirements may be allowed subject to a demonstration test showing that the gas or gases do not affect the NOx reduction rate by more than 2%.

.3 Exhaust gas temperature

The temperature of exhaust gas used for the test should correspond to the temperatures obtained from testing in section 6.2 of these Guidelines, ensuring that the SCR chamber is activated at every load point, other than as provided for by 3.1.4 of the NTC 2008, and that no ammonia bisulphate formation, or reductant destruction, takes place.

.4 Catalyst blocks and AV, SV value

The catalyst blocks used in the test should be representative of the catalyst blocks to be used in the SCR chamber in service. AV, SV or LV value should, in the case of full scale tests, be within -5% or above of the required value as obtained in testing from section 6.2 of these Guidelines. In the case of scaled tests it should correspond to the above.

.5 Reductant

The reductant concentration on the surface of the tested catalyst should be representative of the reductant concentration on the surface of the catalyst during actual engine operation. Ammonia gas may be used as a reductant for the SCR chamber test, provided that it results in an equivalent concentration on the catalyst surface.

6.3.3 **Stability for measurement**

All measurements should be recorded after they have stabilized.

6.3.4 **List of data to be derived from the model**

6.3.4.1 Operating data which is to be given in the Technical File should be derived from the modelling process or otherwise justified.
6.3.4.2 Exhaust gas analysers should be in accordance with appendix III and appendix IV of the NTC 2008 or otherwise to the satisfaction of ISC.
6.3.5 **Test report for SCR chamber**
Data recorded under paragraph 6.3.1.1 of these Guidelines should be recorded in the test report as required by section 5.10 of the NTC 2008.
6.4 Calculation of the specific emission
6.4.1 The NOx emission value of the engine system fitted with SCR should be calculated as follows:

$$gas_x = \frac{\sum_{i=1}^{i=n} ((100-\eta_i)/100) \cdot q_{mgas_i} \cdot W_{F_i}}{\sum_{i=1}^{i=n} (P_i \cdot W_{F_i})}$$

Where: η_i NOx reduction rate (%) derived in accordance with section 6.3 of these Guidelines;

q_{mgas_i} =Mass flow of NOx gas measured in accordance with section 6.2 of these Guidelines;

W_{F_i} =Weighting factor;

P_i =Measured power at individual mode points in accordance with section 6.2 of these Guidelines.

The weighting factors and number of modes (n) used in above calculation shall be according to the provisions of section 3.2 of the NTC 2008.

6.4.2 The NOx emission value (g/kWh) calculated in accordance with paragraph 6.4.1 of these Guidelines should be compared to the applicable emission limit. This emission value is entered into 1.9.6 of the Supplement to the EIAPP certificate (appendix I of the NTC 2008).
6.5 Test report to be submitted to ISC
The test report referenced under paragraphs 6.2.2 and 6.3.5 of these Guidelines, together with the data from section 6.4 of these Guidelines should be consolidated into the overall documentation to be submitted to ISC.

7 ON BOARD CONFIRMATION TEST FOR SCHEME B

7.1 After installation on board of an engine system fitted with SCR and before entry into service an initial confirmation test should be performed on board.
7.2 The engine system fitted with the SCR should be verified as corresponding to the description given in the Technical File.
7.3 The confirmation test should be undertaken as close as possible to 25%, 50% and 75% of rated power, independent of test cycle.
7.4 At each mode point of the confirmation test the operating values as given in the Technical File should be verified.
7.5 NOx emission concentrations should be measured at the inlet and outlet of the SCR chamber. The NOx reduction rate should be calculated. Both values should either be dry or wet. The value obtained for NOx reduction rate should be compared to the initial confirmation test required value at each mode point as given in the Technical File. Reduction efficiency values obtained at each of the test points should not be less than the corresponding values as given in the Technical File by more than 5%.
7.6 The NOx analyser should meet the requirements of chapter 5 of the NTC 2008.
7.7 When an engine system fitted with SCR is in a group defined in chapter 4 of these Guidelines, the confirmation test should be conducted only for the parent engine system of the group. Where the parent engine system of the group is not the first one to complete the onboard confirmation test as required by chapter 7 of these Guidelines, the onboard confirmation test is to be done for all installed engine systems within the engine group unless it is an identical NOx specification member engine or the parent engine system has been installed and tested successfully. Where the parent engine system is not available to be installed on board, the first installed member engine system of the engine group can be chosen and adjusted to the worst case NOx emission for confirmation test on board instead. The test results should be verified as described in the Technical File.

Appendix 15 2018 Guidelines for the Discharge Of Exhaust Gas Recirculation (EGR) Bleed-Off Water

1 INTRODUCTION

1.1 Regulation 13.5 of MARPOL Annex VI requires marine diesel engines to meet the Tier III NOx emission levels when operating in a NOx Tier III emission control area in accordance with the provisions in regulations 13.5.1 and 13.5.2.

1.2 One method for reducing NOx emissions is to use Exhaust Gas Recirculation (EGR), which is an internal engine process resulting in a NOx reduction which will meet the requirements of the regulation. By means of this process, condensate of exhaust gas will be generated and discharged as bleed-off water, which should be handled differently depending on the fuel oil sulphur content. EGR may also be used as a Tier II compliance option.

1.3 These Guidelines cover the discharge of EGR bleed-off water. They are recommendatory in nature; however, the implementation is to be based on these Guidelines.

2 GENERAL

2.1 Purpose

The purpose of these Guidelines is to specify requirements for the discharge to the sea of bleed-off water when using EGR.

2.2 Application

These Guidelines should apply to a marine diesel engine fitted with an EGR device having a bleed-off water discharge arrangement, for which the EIAPP Certificate is first issued on or after 1 June 2019. It should be noted that any discharge of oil or oily mixtures into polar waters is prohibited by the Polar Code (see also paragraphs 3.1 and 3.2 of these Guidelines).

2.3 Definitions

2.3.1 "Bleed-off water" means water to be discharged directly, or via a holding tank, to the sea from an EGR water treatment system.

2.3.2 "EGC" means exhaust gas cleaning.

2.3.3 "EGCS Guidelines" means the *2015 Guidelines for exhaust gas cleaning systems* (resolution MEPC.259(68), as may be amended).

2.3.4 "EGR record book" means a record of the maintenance and servicing of the monitoring equipment required by these Guidelines. This may be met by following the relevant requirements of the EGCS Guidelines. This record would include the date, time, location and quantity of residues delivered ashore from the EGR water treatment system or may be recorded in the EGCS Record Book.

2.3.5 "Manual for EGR bleed-off discharge system" means the manual containing the system description, discharge limits and the relevant items required for Onboard Monitoring Manual (OMM) in the EGCS Guidelines or the Revised Guidelines.

2.4 Required documents

The EGR record book and manual for EGR bleed-off discharge system should be approved by ISC. The following documents should be retained on board the ship as appropriate and should be available for surveys as required:

.1 manual for EGR bleed-off discharge system;

.2 certificates for type approval of oil content meters (15 ppm alarm);

.3 operating and maintenance manuals of oil content meters (15 ppm alarm); and

.4 EGR record book.

3 DISCHARGE OF EGR BLEED-OFF WATER INTO THE SEA

3.1 Bleed-off water when using fuel oil not complying with the relevant limit value in regulation 14 of MARPOL Annex VI

3.1.1 The bleed-off water discharged to the sea from an EGR water treatment system may or may not be combined with the discharge water from an EGC system. In either case, this discharge to the sea should be documented, monitored and recorded, as appropriate, in accordance with the relevant requirements of the EGCS Guidelines. Upon request, ISC should be provided with bleed-off water samples according to appendix 3 of the EGCS Guidelines, as applicable.

3.1.2 Bleed-off water which is retained onboard in a holding tank should not be discharged to the sea, except when:

.1 the ship is en route[2] and outside polar waters, [3]ports, harbours or estuaries; and

.2 the bleed-off water discharged meets the provisions of paragraph 3.1.1.

3.2 Bleed-off water when using fuel oil complying with the relevant limit value in regulation 14 of MARPOL Annex VI

3.2.1 In case the EGR system is in operation and the sulphur content of the fuel oil used for the engine complies with regulation 14 of MARPOL Annex VI, the discharge of bleed-off water should meet the requirements of paragraph 3.1, unless the following conditions are satisfied:

.1 the ship is en route[2] outside polar waters,[3] ports, harbours or estuaries;

.2 the sulphur content of the fuel oil used for the engine when the EGR system is in operation complies with the relevant requirements of regulation 14 of MARPOL Annex VI;

.3 the oil content meter is type approved in accordance with the annex of resolution MEPC.107(49), as amended;

.4 the oil content of the bleed-off water discharge and 15 ppm alarm is continuously monitored and recorded; and

.5 the oil content of the discharge does not exceed 15 ppm.

3.2.2 When the EGR system is operated in polar waters,[3] ports, harbours or estuaries, the discharge of bleed-off water to the sea should comply with section 3.1.

3.2.3 Bleed-off water which is retained on board in a holding tank should not be discharged to the sea, except when:

.1 the ship is en route[2] and outside polar waters, [3] ports, harbours or estuaries; and

.2 the bleed-off water discharged meets the provisions of paragraph 3.2.1.

4 RESIDUES FROM EGR WATER TREATMENT SYSTEMS

4.1 Residues from EGR water treatment systems should be delivered ashore to adequate reception facilities. Such residues should not be discharged to the sea or incinerated on board.

4.2 Each ship fitted with an EGR unit should record the storage and disposal of bleed-off water residues in an EGR record book, including the date, time and location of such storage and disposal.

5 BLEED-OFF WATER ADDITIVES

[2]Refer to Unified Interpretation to regulation 15.2.1 of the revised MARPOL Annex I (MEPC 55/23, annex 18).

[3]Refer to the *International Code for Ships Operating in Polar Waters* (Polar Code) (resolutions MEPC.264(68) and MSC.385(94)).

5.1 In case additives are used for enhancing the bleed-off water quality, an assessment of the additive should be performed and documented unless the below substances are used and documented with a Material Safety Data Sheet:

.1 neutralization agent (caustic substance), such as Sodium Hydroxide (NaOH) or Sodium Carbonate (Na2CO3); and

.2 flocculants, which are used for marine approved oily-water separating equipment.

5.2 For those technologies which make use of chemicals, additives, preparations or create relevant chemicals, not including those in paragraph 5.1, in situ, there should be an assessment of the bleed-off water additives. The assessment could take into account relevant guidelines such as the *Procedure for approval of ballast water management systems that make use of active substances (G9)* (resolution MEPC.169(57)), and, if necessary, additional bleed-off water discharge criteria should be established.

6 SURVEY AND CERTIFICATION

The bleed-off discharge system and the EGR record book should be subject to survey on installation and at initial, annual/intermediate and renewal surveys by ISC. The bleed-off discharge system and the EGR record book may also be subject to inspection by Port State Control.