GUIDELINES REGARDING THE REQUIREMENTS FOR MARINE DIESEL ENGINES
FITTED WITH NOₓ SELECTIVE CATALYTIC REDUCTION (SCR) SYSTEMS

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1 INTRODUCTION

1.1 The present Publication is based on the requirements of Resolution MEPC.198(62) adopted on 15 July 2011, as amended by Resolution MEPC.280(68) in May 2015.

1.2 The use of NO\textsubscript{x}-reducing devices is envisaged in Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines, 2008 (NO\textsubscript{x} Technical Code, 2008) as given in section 2.2.5 and a Selective Catalytic Reduction (SCR) system is one of such devices.

1.3 NO\textsubscript{x} Technical Code, 2008 contains two ways for pre-certification of engine systems fitted with NO\textsubscript{x}-reducing devices:

\begin{itemize}
  \item[1.] engine fitted with SCR: approval in accordance with paragraph 2.2.5.1 of the NO\textsubscript{x} Technical Code, 2008:
  \begin{quote}
  "Where a NO\textsubscript{x}-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 Technical File. The engine shall be tested, at the pre-certification test, with the NO\textsubscript{x}-reducing device fitted...
  \end{quote}

  The tests shall be carried out in accordance with Chapter 5 of the NO\textsubscript{x} Technical Code, 2008; and

  \item[2.] the simplified measurement method in accordance with section 6.3 of the NO\textsubscript{x} Technical Code, 2008 as regulated in paragraph 2.2.5.2 of the NO\textsubscript{x} Technical Code:
  \begin{quote}
  "In those cases where a NO\textsubscript{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\textsubscript{x} emission limit. However, in this case, the assembly may be re-tested in accordance with simplified measurement method in accordance 6.3. In no case shall the allowances given in 6.3.11 be granted."
  \end{quote}
\end{itemize}

1.4 According to paragraph 2.2.5.1 of the NO\textsubscript{x} Technical Code, 2008, the engine fitted with SCR shall be tested on a test bed applying Scheme A procedures (see Chapter 5 of the present Publication). Where this is not appropriate, given reasons as outlined in 3.1.1 of this Publication, the Scheme B procedures shall be applied (see Chapter 6 of the present Publication).

2 GENERAL

2.1 Purpose

The purpose of the present Publication is to provide guidance in addition to the requirements of the NO\textsubscript{x} Technical Code, 2008, for design, testing, surveys and certification of marine diesel engines fitted with SCR system to ensure their compliance with the requirements of regulation 13 of MARPOL Annex VI.

2.2 Application

The present 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 used in the present Publication have the same meaning as the terms defined in regulation 2 of MARPOL Annex VI and in section 1.3 of the NO\textsubscript{x} Technical Code, 2008.

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.\footnote{With effect from 1 August 2013, the paragraphs 2.2.4 and 2.2.5.1 of the NO\textsubscript{x} Technical Code, 2008 have been amended by Resolution MEPC.217(63).}

\footnote{With effect from 1 September 2017, the paragraphs 1.3.10 of the NO\textsubscript{x} Technical Code, 2008 have been amended by Resolution MEPC.272(69).}
**Engine system fitted with SCR** – a system consisting of a marine diesel engine, a SCR chamber and a reductant injection system. When a control device on NO\textsubscript{X} reducing performance is provided, it is also regarded as a part of the system.

**Catalyst block** – a block of certain dimensions through which exhaust gas passes and which contains catalyst composition on its inside surface to reduce NO\textsubscript{X} from exhaust gas.

**SCR chamber** – an integrated unit, which contains the catalyst block(s) and into which flows exhaust gas and reductant.

**Reductant injection system** – 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.

\[ \text{NO}_{X} \text{ reduction rate, [%]} = \left( \frac{c_{\text{inlet}} - c_{\text{outlet}}}{c_{\text{inlet}}} \right) \times 100 \]

where:

- \(c_{\text{inlet}}\) – NO\textsubscript{X} concentration as measured at the inlet of the SCR chamber, [ppm];
- \(c_{\text{outlet}}\) – NO\textsubscript{X} concentration as measured at the outlet of the SCR chamber, [ppm].

**Area velocity (AV)**, [m/h] – a value of the exhaust gas flow rate passing through the catalyst block(s) [m\textsuperscript{3}/h] per total active surface area of the catalyst blocks in the SCR chamber [m\textsuperscript{2}]. The exhaust gas flow volume is the volume defined at 0 °C and 101.3 kPa.

**Linear velocity (LV)**, [m/h] – a value of the exhaust gas flow rate passing through the catalyst blocks [m\textsuperscript{3}/h] per catalyst block’s section [m\textsuperscript{2}] in a normal direction of exhaust gas flow. The exhaust gas flow volume is the volume defined at 0 °C and 101.3 kPa.

**Block section**, [m\textsuperscript{2}] – the cross-sectional area of the catalyst block based on the outer dimensions.

**Space velocity (SV)**, [1/h] – a value of the exhaust gas flow rate passing through the catalyst block(s) [m\textsuperscript{3}/h] per total volume of the catalyst block(s) in the SCR chamber [m\textsuperscript{3}]. The exhaust gas flow is the volume defined at 0 °C and 101.3 kPa.

**Total volume of catalyst block**, [m\textsuperscript{3}] – the volume based on outer dimensions of the catalyst block.

### 3 PRE-CERTIFICATION PROCEDURE FOR ENGINES FITTED WITH SCR SYSTEM

#### 3.1 General

.1 Engine systems fitted with SCR shall be certified in accordance with Chapter 2 of the NO\textsubscript{X} Technical Code, 2008. In cases where combined engine/SCR systems can neither be tested on a test bed due to their size, construction and other restrictions nor an on board test can be performed fully complying with the requirements of Chapter 5 of the NO\textsubscript{X} Technical Code, 2008, the procedures provided by Scheme B of the present guidelines shall be applied.

.2 The applicant for certification should be the entity responsible for the complete engine system fitted with SCR, e.g. the engine manufacturer.

.3 The applicant shall supply all necessary documentation, including the Technical File for the complete system, a description of the required on board NO\textsubscript{X} verification procedures and, where applicable, the description of the confirmation test procedure (NO\textsubscript{X} limits should be met).

#### 3.2 Technical File and On Board NO\textsubscript{X} Verification Procedures

In addition to the information given in 3.1.3 of these guidelines and the items in section 2.4 of the NO\textsubscript{X} Technical Code, 2008, engine systems fitted with SCR shall include the following information in the engine 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;
.4 catalyst block specification and arrangement in the SCR chamber;
inlet parameters including allowable exhaust gas temperature (maximum and minimum) at the inlet of the SCR chamber;

cross-unit parameters: allowable pressure loss ($\Delta p$) between inlet and outlet of the SCR chamber and in the exhaust duct caused by SCR system components;

aspects related to the fuel oil quality resulting in continued compliance of the engine with the applicable NO$_X$ emission limit;

factors related to the deterioration rate of SCR performance, e.g. exchange condition for SCR blocks and recommended exchange time of SCR blocks;

controlling arrangements and settings of the SCR, e.g. model, specification of control device;

measures to minimize reductant slip;

parameter check method as the verification procedure: with regard to the application of the parameter check method, the requirements given in 2.3.6 of the NO$_X$ Technical Code, 2008 and guidance given in Appendix VII, paragraph 2 of the NO$_X$ Technical Code, 2008 shall be taken into account in assessing the adequacy of a proposed procedure with analysers meeting or exceeding the requirements of Appendix III of the NO$_X$ Technical Code, 2008; and

any other parameter(s) specified by the manufacturer.

3.3 Measures to Minimize Reductant Slip

When SCR uses urea solution, ammonia solution or ammonia gas as reductant, measures to prevent reductant slip shall be provided to avoid the supply of an excessive amount of reductant in the system. The reductant injection system shall be designed to prevent emissions of any harmful substance from the system.

3.4 Pre-certification Procedure for an Engine System Fitted with SCR

Tests and pre-certification of an engine system fitted with SCR shall be conducted either by Scheme A (as given in Chapter 5 of these guidelines) or by Scheme B (as given in Chapters 6 and 7 of these guidelines), as appropriate.

3.5 EIAPP Certificate

An Engine International Air Pollution Prevention (EIAPP) Certificate for NO$_X$ emission (see Appendix I to the NO$_X$ Technical Code, 2008) should be issued by the Administration after approval of the Technical File.

When an applicant chooses the Scheme B for pre-certification, the International Air Pollution Prevention (IAPP) Certificate initial survey should be not be completed until on board initial confirmation test provides compliant results. The applicant remains the responsible entity until the final acceptance of the system.

4 FAMILY AND GROUP CONCEPTS FOR ENGINE SYSTEMS FITTED WITH SCR

The requirements specified in Chapter 4 of the NO$_X$ Technical Code, 2008 apply equally to engine systems fitted with SCR.

5 TEST PROCEDURES FOR ENGINES FITTED WITH SCR IN SCHEME A

5.1 General

Tests of a combined system of an engine fitted with SCR in Scheme A shall ensure compliance with the applicable NO$_X$ emission limits of MARPOL Annex VI. The test bed measurement procedures of Chapter 5 of the NO$_X$ Technical Code, 2008 shall apply.

5.2 Calculation of Gaseous Emission

5.2.1 The calculation method, presented in section 5.12 of the NO$_X$ Technical Code, 2008, is also applicable 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 NOX Technical Code, 2008). The NOX correction factors for humidity and temperature (equations (16) or (17), paragraphs 5.12.4.5 and 5.12.4.6, respectively, of the NOX Technical Code, 2008) should not be applied.

Note: The calculation method presented in subchapter 5.12 of NOX Technical Code applies to both certification methods A and B for engines with fitted SCR system.

5.2.2 For an engine system fitted with SCR, the following parameters shall be measured and recorded in the engine test report in accordance with 5.10 of the NOX Technical Code, 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 ($\Delta p$). If the manufacturer sets an allowable limit of $\Delta p$, it shall be confirmed; and
4. other parameter(s) as specified by PRS.

6 TEST PROCEDURES FOR ENGINES FITTED WITH SCR IN SCHEME B

6.1 General

Tests of a combined system of an engine fitted with SCR in Scheme B shall ensure that the system complies with the applicable NOX emission limits of MARPOL Annex VI. The test procedures in Scheme B are as follows:

1. an engine shall be tested to obtain the NOX emission value, [g/kWh], in accordance with 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. a SCR chamber, not necessarily to full-scale, shall be tested in accordance with 6.3 of these guidelines in order to generate data for the calculation model as that used in 6.1.2 of these guidelines;
4. the NOX emission from the engine system fitted with SCR shall be calculated in accordance with 6.4 of these guidelines using the NOX emission value from the engine and the NOX reduction rate of SCR chamber. The Technical File shall be completed and the NOX emission value entered into the Supplement to EIAPP Certificate; and
5. the NOX emission performance of the engine combined with the SCR shall be verified by a confirmation test in accordance with the procedure specified in 7.5 of these guidelines.

Note: The calculation of gaseous emissions in 6.1.1 should be undertaken in accordance with 5.2.1.

6.2 Verification Test Procedures for an Engine

6.2.1 The purpose of the tests of an engine is to establish the emission values for use in 6.4 of these guidelines. The measurements shall be in accordance with Chapter 5 of the NOX Technical Code, 2008.

6.2.2 Paragraph 5.9.8.1 of the NOX Technical Code, 2008 requires engine conditions to be measured at each mode point only after the engine has been stabilized. 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 NOX Technical Code, 2008.

6.3 Test Procedures for SCR Chambers

6.3.1 General

The SCR chamber for validation testing may be either a full-scale SCR chamber or a scaled version. A SCR chamber shall demonstrate the reduction in NOX concentrations [ppm] expected in exhaust gas...
measured in 6.2 of these guidelines. Therefore, NO\textsubscript{X} reduction rate of the SCR chamber shall be determined for each individual mode point. Where validation tests are conducted on a scaled version of the SCR chamber, the scaling process shall be approved by PRS.

### 6.3.2 Test Conditions at Each Mode Point

Exhaust gas, catalyst, reductant and an injection system shall satisfy the following conditions at each mode point:

1. **Exhaust gas flow**
   - Exhaust gas flow rate for the test shall be scaled accordingly to account for the dimensions 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 shall correspond, with regard to concentrations, to the exhaust gas as specified in 6.2 of these guidelines in terms of NO\textsubscript{X}, \text{O}_2, \text{CO}_2, \text{H}_2\text{O} and SO\textsubscript{2} (±5\% of the required concentration for each emission species).
   - Where simulated gas is used, it shall correspond, with regard to concentrations, to the exhaust gas as specified in 6.2 of these guidelines in terms of NO, NO\textsubscript{2}, \text{O}_2, \text{CO}_2, \text{H}_2\text{O} and SO\textsubscript{2} (±5\% of the required concentration for each emission species) balance N\textsubscript{2}.

3. **Exhaust gas temperature**
   - The temperature of exhaust gas used for the test shall correspond to the temperature obtained from testing according to 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 NO\textsubscript{X} Technical Code, 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 shall be representative of the catalyst blocks to be used in the SCR chamber in service. AV, SV or LV value shall, in the case of full-scale tests, be within a range of ±20\% of the required value as obtained in testing according to 6.2 of these guidelines.
   - In the case of scaled test, it shall correspond to the above.

5. **Reductant**
   - The reductant concentration shall be representative of the reductant concentration in the exhaust gas during actual operation.

### 6.3.3 Stability for Measurement

All measurements shall be recorded after they have stabilized.

### 6.3.4 List of Data to be Derived from the Model

1. **Operating data**
   - To be given in the Technical File shall be derived from the modelling process or otherwise justified.

2. **Exhaust gas analysers**
   - Shall be in accordance with Appendix III and Appendix IV of the NO\textsubscript{X} Technical Code, 2008 or otherwise to the satisfaction of PRS.

### 6.3.5 Test Report for SCR Chamber

Data recorded in accordance with 6.3.1 of these guidelines shall be entered into test report as required in section 5.10 of the NO\textsubscript{X} Technical Code, 2008.

### 6.4 Calculation of the Specific Emission

#### 6.4.1 The NO\textsubscript{X} emission value of the engine system fitted with SCR shall be calculated as follows:

\[
gas_x = \frac{\sum_{i=1}^{n} \left( (100 - \eta_i) / 100 \right) \cdot d_{\text{gas}_i} \cdot W_{Fi}}{\sum_{i=1}^{n} (P_i \cdot W_{Fi})}
\]  

(6.4.1-1)

where:

- \( \eta_i \) – NO\textsubscript{X} reduction rate derived in accordance with 6.3 of these guidelines, [%];
\( q_{\text{mgas} i} \) – mass flow of NO\(_X\) gas measured in accordance with 6.2 of these guidelines;
\( W_{Fi} \) – weighting factor;
\( P_i \) – measured power at individual mode points in accordance with 6.2 of these guidelines, [kW].

The weighting factors and the number of modes used in the above calculation shall be according to the provisions of section 3.2 of the NO\(_X\) Technical Code, 2008.

6.4.2 The NO\(_X\) emission value [g/kWh] calculated in accordance with 6.4.1 of these guidelines, shall be compared to the applicable emission limit. The emission value is entered into item 1.9.6 of the Supplement to the EIAPP Certificate (Appendix I of the NO\(_X\) Technical Code, 2008).

6.5 Test Report

The test report, referred to in paragraphs 6.2.2 and 6.3.5 of these guidelines, together with the data given in 6.4 of these guidelines, shall be consolidated into the overall documentation to be submitted to PRS for approval.

7 ON BOARD CONFIRMATION TEST FOR SCHEME B

7.1 After installation on board of an engine fitted with SCR and before entry into service, an initial confirmation test shall be performed on board (NO\(_X\) limits should be met).

7.2 The engine system fitted with SCR shall be verified as corresponding to the description given in the Technical File.

7.3 The confirmation test shall be conducted, as far as practicable, for 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 shall be verified.

7.5 NO\(_X\) emission concentrations shall be measured at the inlet and outlet of the SCR chamber. The NO\(_X\) reduction rate shall be calculated. Both values should be measured for either dry or wet conditions. The value obtained for NO\(_X\) reduction rate shall 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 shall be not less than the corresponding values given in the Technical File by more than 5%.

7.6 The NO\(_X\) analyzer shall comply with the requirements specified in Chapter 5 of the NO\(_X\) Technical Code, 2008.

7.7 When an engine system fitted with SCR is in a group defined in Chapter 4 of the present Publication, the confirmation test shall be conducted only for the parent engine system of the group.

List of amendments effective as of 1 January 2016

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