ANNEX 5

DRAFT AMENDMENTS TO THE NO_x TECHNICAL CODE 2008

(Use of multiple engine operational profiles for a marine diesel engine, including clarifying engine test cycles)[1]

Chapter 1 – General

1.3 Definitions

1 Paragraph 1.3.2 is replaced by the following:

"1.3.2 *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 applicable emission limit set out in regulation 13. Routine replacement of engine components by parts specified in the technical file that do not alter emission characteristics shall not be considered a "substantial modification" regardless of whether one part or many parts are replaced. For the recertification of such an engine following a substantial modification, the version of the NO_x Technical Code that was used for the original certification will apply except if the engine was or is now equipped with an auxiliary control device or has multiple engine operational profiles. Where an auxiliary control device is fitted, the requirements of 2.5 and 3.3 of this Code will apply. Where there are multiple engine operating profiles the requirements of chapter 8 of this Code will apply.

.2 For engines installed on ships constructed before 1 January 2000, *substantial modification* means any modification made to an engine that 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 is not considered to be a substantial modification for the purpose of the application of regulation 13.2 of the annex. For recertification of such an engine following a substantial modification, 2.5, 3.3 and, where that engine has multiple engine operating profiles, chapter 8 of this Code will apply."

[1] Note: upon adoption by MEPC 83, the draft amendments set out in this annex are expected to enter into force in March 2027 (same entry-into-force date as that of the revised MARPOL Annex VI).

2 New paragraphs 1.3.21 to 1.3.37 are added as follows:

"1.3.21 *Engine operational profile* means a particular set of NO_x influencing settings applied in the base emission control strategy which influences the NO_x emission performance. Those settings may relate to, but are not limited to, fuel injection, inlet and exhaust valve operation, charge air management, exhaust bypass/wastegate or exhaust after-treatment controls and auxiliary control devices.

1.3.22 *Multiple engine operational profiles* means that more than one engine operational profile is available for selection on a marine diesel engine.

1.3.23 *Auxiliary control device* means a system, function or control strategy installed on a marine diesel engine that is used to protect the engine and/or its ancillary equipment against operating conditions that could result in damage or failure, or that is used to facilitate the starting of the engine. An auxiliary control device may also be a strategy or measure that has been satisfactorily demonstrated not to be a defeat device. An auxiliary control device includes any element of design that includes sensors, or other arrangements which, by an action of the control system, can activate, modulate, delay or deactivate the operation of any part of the base emission control system. Any device or strategy the activation of which causes a non-progressive change in emissions is also an auxiliary control device. An auxiliary control device not declared at the time of the first certification of a marine diesel engine shall be considered a defeat device.

1.3.24 *Defeat device* means a device that 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. An auxiliary control device accepted as part of the Administration's review of the NO_x certification pack is not a defeat device.

1.3.25 *Base emission control strategy* means the emission control strategy active at any time an auxiliary control device is not active. It consists of any parameter, element of design, or operating control that is designed to modulate as a function of engine load and/or speed in a manner that affects the emission performance of the engine. The modulation of parameters is to be progressive and not result in disproportionate change in emissions.

1.3.26 *Rational emission control strategy* means the base emission control strategy applied to a marine diesel engine which ensures that the emission values at the individual mode points as used to give the weighted specific emission value are representative of the emission values during normal operation of the engine.

1.3.27 *Irrational emission control strategy* means any strategy or measure that, when a marine diesel engine is operated under normal conditions of use, reduces the effectiveness of an emission control system to a level below that expected from the applicable emission test procedures.

1.3.28 *Not to exceed emission limit value* means the maximum permitted NO_x emission value at a given operating condition as determined in accordance with 3.3 of this Code within the not to exceed zone of the engine.

1.3.29 *Not to exceed zone* means the power or torque and speed area of a marine diesel engine within the limit area of the not to exceed zone as declared by the applicant that the engine is certified to operate within under steady-state conditions. In the case of the C1 cycle, as given by 3.2 of this Code, the not to exceed zone corresponds to the whole of the limit area of the not to exceed zone.

1.3.30 *Limit area of the not to exceed zone* means the power or torque and speed boundaries of the not to exceed zone at and above 25% rated power for all test cycles as given by 3.2 of this Code except for the C1 cycle where it is at and above 50% engine load.

1.3.31 *Point emission value* means the NO_x emission value expressed in terms of g/kWh at the reference conditions of humidity and temperature given by this Code at a particular power or load and speed point.

1.3.32 *NO_x certification pack* means the package of information supplied by the applicant to the Administration as required to be submitted by 2.5 and 3.3 of this Code.

1.3.33 *Propulsion engine* means a marine diesel engine that is used for direct or indirect propulsion. A propulsion engine may additionally perform non-propulsion duties during or separately to propulsion duties.

1.3.34 *Non-propulsion engine* means a marine diesel engine that is not a propulsion engine. An engine that solely or in part provides athwartships movement of a ship is not a propulsion engine.

1.3.35 *Constant-speed engine* means a marine diesel engine that is limited to constant-speed operation.

1.3.36 *Constant-speed engine operation* means a marine diesel engine regulated by a speed control device that automatically controls the operator demand to maintain engine's nominal speed across the load range.[2]
Additionally, an idle speed setting may be provided that can be used during start-up or shutdown.

1.3.37 *Variable-speed engine* means an engine that is not a constant-speed engine."

Chapter 2 – Surveys and certification

3 A new section 2.5 is added as follows:

"**2.5 Rational emission control strategy**

2.5.1 In addition to 2.2, the requirements of this section shall apply.

2.5.2 A rational emission control strategy shall be applied to each marine diesel engine across the whole of its operating load and speed range. The means by which that is achieved shall be documented by the applicant to the Administration within a NO_x certification pack. The information included in that pack shall be such as to demonstrate to the satisfaction of the Administration that a rational emission control strategy is applied during normal operation of the engine.

[2] In service, such a speed control device may either maintain a fixed speed or a load dependent speed such that at maximum load the speed could be up to around 10% lower than at zero load.

2.5.3 For an engine where one or more auxiliary control devices are applied, each of those shall be declared to the Administration within the NO_x certification pack irrespective of whether those operate under steady-state or transient conditions. An auxiliary control device which is not so declared shall be considered a defeat device and hence invalidate the NO_x certification of an engine to which such an undeclared device is applied.

2.5.4 For screening of the base emission control strategy, the NO_x certification pack shall include:

.1 a list of all NO_x emission influencing setting and operating values controlled by an engine's base emission control strategy, for example, but not limited to fuel injection, inlet and exhaust valve operation, charge air management, exhaust bypass/wastegate or exhaust after-treatment controls;

2. a record of the reference values for the settings and operating values identified in 2.5.4.1 at each of the mode points of the applicable test cycle;

.3 documentation that whenever the engine is operating between two mode points as identified in 2.5.4.2, the emission control strategy interpolates progressively between the mode points;

.4 documentation to show that, along lines of constant power and varying speed from the line between the mode points to the limit area of the not to exceed zone of the engine, the base emission control strategy shall ensure that any variation in the point emission values is progressive and justified from the value at that power on the line between the mode points, unless rationalized by an auxiliary control device or explained by a physical limitation of the engine;

.5 a declaration that the engine's base emission control strategy only reacts to changes in engine load and speed;

.6 any other information the applicant considers relevant; and

.7 any other information the Administration requests.

2.5.5 For each auxiliary control device which may operate under steady-state conditions the NO_x certification pack shall include:

.1 a justification of the need for that device; and

.2 a description for that device, including:

.1 details of the conditions under which that device will operate and the functioning of that device;

.2 how each modulated parameter of the emission control system achieves the stated purpose of the base emission control strategy;

.3 the process used to ensure that the modulation is limited to the conditions where the stated purpose of the auxiliary control device operational strategy arises and to set the modulation to be the minimum necessary to achieve that stated purpose;

.4 the effect of the application of that device on the engine's base emission control strategy;

.5 for auxiliary control devices that operate above 25% engine power, the effect on the point emission values shall be documented;

.6 for auxiliary control devices that operate within the declared not to exceed zone, an estimate of the effect on the point emission values shall be documented;

.7 any other information the applicant considers relevant; and

.8 any other information the Administration requests.

.3 Auxiliary control devices that only operate during transient conditions need not be included in the NO_x certification pack for screening.

2.5.6 The technical file as required by 2.3.4 shall contain the following information:

.1 identification of those auxiliary control devices declared under 2.5.3;

.2 for those auxiliary control devices covered under 2.5.5, the operating conditions which will cause those devices to function;

.3 the means by which the operation of those auxiliary control devices under 2.5.5 may be verified as part of the onboard NO_x verification procedure; and

.4 where the provisions of 2.3.6 apply, the means by which it is to be verified that the required quantities of additional substance used are consistent with achieving the engine's intended base emission control strategy shall be included as part of the onboard NO_x verification procedure.

2.5.7 Where acceptable to the Administration, the documentation requirements of 2.5.4 and 2.5.5 may alternatively be made by reference to that in respect of marine diesel engines comparable, in terms of NO_x emissions characteristics, to the engine to be certified.

2.5.8 The provisions of this section only apply to a marine diesel engine which is installed in a ship as an identical replacement engine if the requirements of this section applied at the time the engine family or engine group to which that engine belongs was first certified."

Chapter 3 – Nitrogen oxides emission standards

3.1 Maximum allowable NO_x emission limits for marine diesel engines

4 Paragraph 3.1.4 is replaced by the following:

"3.1.4 In the case of a marine diesel engine to be certified in accordance with paragraph 5.1.1 of regulation 13, the specific emission at each individual mode point shall not 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 3.2.4.

.2 The 10% mode point in the C1 test cycle specified in 3.2.5.

.3 The idle mode point in the C1 test cycle specified in 3.2.5."

3.2 Test cycles and weighting factors to be applied

5 Section 3.2 is replaced by the following:

"**3.2 Test cycles and weighting factors to be applied**

3.2.1 For every individual engine or parent engine of an engine family or engine group, one or more of the relevant test cycles specified in 3.2.2 to 3.2.5 shall be applied for verification of compliance with the applicable NO_x emission limit contained in regulation 13. Appendix IX provides guidance on the selection of the appropriate test cycle but where discrepancies exist the text of chapter 3 takes precedence.

3.2.2 For a fixed pitch propeller propulsion engine or a propeller-law operated non-propulsion engine, test cycle E3 shall be applied in accordance with table 1.

3.2.3 For a propulsion engine that does not operate with a fixed pitch propeller, including an engine fitted as part of a diesel-electric installation or an engine operated with a controllable-pitch propeller, test cycle E2 shall be applied in accordance with table 2.

3.2.4 For a non-propulsion engine that is a constant-speed engine, test cycle D2 shall be applied in accordance with table 3.

3.2.5 For a non-propulsion engine that operates as a variable-speed engine, not included above, test cycle C1 shall be applied in accordance with table 4.

Table 1 – *Test cycle for a marine diesel engine meeting paragraph 3.2.2*

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

Table 2 – *Test cycle for a marine diesel engine meeting paragraph 3.2.3*

Test cycle E2	Speed	100%	100%	100%	100%[3]
	Power	100%	75%	50%	25%
	Weighting factor	0.2	0.5	0.15	0.15

Table 3 – *Test cycle for a marine diesel engine meeting paragraph 3.2.4*

Test cycle 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

Table 4 – *Test cycle for a marine diesel engine meeting paragraph 3.2.5*

Test cycle 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

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

3.2.7 The intermediate speed for test cycle C1 shall be declared by the manufacturer, taking into account the following requirements:

.1 For engines that are designed to operate over a speed range on a full load torque curve, the intermediate speed shall 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 shall 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 shall be 75% of rated speed.

.4 For engines that 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.

3.2.8 If an engine manufacturer applies for a new test cycle application on an engine already certified under a different test cycle specified in 3.2.2 to 3.2.5, then it may not be necessary for that engine to undergo the full certification process for the new

[3] There are exceptional cases, including large bore engines intended for E2 applications, in which, owing 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 shall make application to the Administration that the test cycle as given in table 2 above may be modified for the 25% power mode with regard to the engine speed. The adjusted engine speed at 25% power, however, shall be as close as possible to the rated engine speed, as recommended by the engine manufacturer and approved by the Administration. The applicable weighting factors for the test cycle shall remain unchanged.

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."

6 A new section 3.3 is added as follows:

"**3.3 Not to exceed emission values within the limit area of the not to exceed zone**

3.3.1 The boundaries, in terms of power or torque and speed, of the not to exceed zone at or above 25% power are to be declared to the Administration by the applicant as part of the NO_x certification pack. Operation outside these not to exceed zone boundaries, within the limit area of the not to exceed zone, shall only be permitted during starting, stopping, accelerations, deceleration, load pick-up or load rejection. However, operation below 25% power and at or above 63% speed for the E3, E2, and D2 test cycles and below 50% load for the C1 test cycle shall be permitted subject to it being shown in accordance with the requirements of 2.5 that a rational emission control strategy continues to be applied.

3.3.2 The technical file as required by 2.3.4 shall additionally contain the following information:

.1 the power or torque and speed boundaries, as given by 3.3.1, within which the engine is certified to operate; and

.2 the onboard NO_x verification procedure shall include means to verify that the engine only operates within the power or torque and speed boundaries as given by 3.3.1.

3.3.3 Additional to the emission testing under 3.2 the Administration may, at its discretion, require that up to three point emission values be determined at load points within the not to exceed zone in order to verify that the not to exceed zone requirements are complied with. The load points to be tested shall be agreed between the applicant and the Administration as part of the review of the NO_x certification pack. Point emission values are to be determined in accordance with the procedures given by chapter 5 and appendix X. To be acceptable each of those point emission values so determined shall not exceed the respective not to exceed emission limit value, N_{Lz}, as determined using the procedure in appendix X.

Point emission value ≤ emission limit value, N_{Lz}, at that point

3.3.4 Alternative means by which it is to be shown that a point emission value may be determined or the not to exceed zone requirements are complied with may be used subject to their acceptability to the Administration.

3.3.5 For member engines of engine families or engine groups first certified prior to the entry into force of the requirements under this section, demonstration of compliance with the requirements of this section may be on the basis solely of documentation which is to be acceptable to the Administration."

Chapter 4 – Approval of serially manufactured engines: Engine family and engine group concepts

7 In paragraph 4.3.8.2, sub-paragraphs 4.3.8.2.12 to 4.3.8.2.14 are added, after the existing sub-paragraph 4.3.8.2.11, as follows:

".12 multiple engine operational profiles as covered by chapter 8.

.13 base emission control strategy.

.14 auxiliary control devices."

8 Paragraph 4.3.10.5 is deleted.

Chapter 6 – Procedures for demonstrating compliance with NO_x emissions on board

9 In paragraph 6.2.2.3, at the end of sub-paragraph 6.2.2.3.15, the word "or" is deleted, at the end of sub-paragraph 6.2.2.3.16, "." is replaced with ",", and new sub-paragraphs 6.2.2.3.17 to 6.2.2.3.19 are added after sub-paragraph 6.2.2.3.16 as follows:

".17 list of identification references of all engine operational profiles available for the engine and, if applicable, the conditions under which each is to be used (see chapter 8),

.18 list of auxiliary control devices accepted for the engine and the operating conditions under which those devices function, or

.19 the engine power or engine load and speed boundaries above 25% engine power within which the engine is certified to operate."

10 A new chapter 8 is added as follows:

"**Chapter 8 – Multiple engine operational profiles**

8.1 Acceptance of multiple engine operational profiles

8.1.1 The switching between engine operational profiles under onboard conditions is permitted, subject to the provisions of this chapter, in the following cases:

.1 for a marine diesel engine certified to be in-service switchable between emission Tiers;

.2 for a marine diesel engine certified to more than one test cycle application in accordance with 3.2 where the engine operational profile is in-service switchable based on the duty the engine is performing; or

.3 for a marine diesel engine certified to the same emission standard, the same rated power, same rated speed and the same test cycle which is in-service switchable between multiple engine operational profiles.

8.1.2 A marine diesel engine certified in accordance with 8.1.1.1 and/or 8.1.1.2 may additionally be switchable, at a particular tier and or duty, between multiple engine operational profiles in which cases the provisions of 8.1.1.3 also apply.

8.1.3 Each engine operating profile is to be identified in the technical file as required by 2.3.4 together with the conditions, if applicable, under which each engine operating profile is to be used.

8.2 Certification of multiple engine operational profiles

8.2.1 For a marine diesel engine to which 8.1.1.1 applies, the parent engine test report for each tier shall be included in the technical file as required by 2.4.1.5. The parent engine specific emission value for each tier shall be entered under 1.9.6 of the Supplement to the EIAPP Certificate.

8.2.2 For a marine diesel engine to which 8.1.1.2 applies, the parent engine test report for each test cycle shall be included in the technical file as required by 2.4.1.5. The test cycles for which the engine is certified shall be shown on the EIAPP Certificate. The parent engine specific emission value for each test cycle shall be entered and identified under 1.9.6 of the Supplement to the EIAPP Certificate.

8.2.3 For a marine diesel engine to which 8.1.1.3 applies:

.1 the engine test report for each engine with the parent engine features and characteristics identified in 4.3.9 or 4.4.8, for each engine operational profile, shall be determined in accordance with the provisions of chapter 5 of this Code. Where there is a mode point condition which is the same among the different engine operational profiles, that is not required to be repeated for each test cycle. The required testing may not necessarily be undertaken on the same physical engine;

.2 the specific emission value determined in accordance with 5.12.6.1 for each engine operational profile shall not exceed the applicable limit value as given by regulation 13;

.3 the multiple engine operational profile parent engine specific emission value shall be determined in accordance with 5.12.6.1 from the highest NO_x emission rate, q_{mgasi} as per 5.12.5.2, at each mode point across all the engine operational profiles for which the engine is to be certified;

.4 the parent engine test report for each engine operational profile for which the engine is to be certified shall be included in the technical file as required by 2.4.1.5 together with the determination of the multiple engine operational profile parent engine specific emission value;

.5 the multiple engine operational profile parent engine specific emission value shall be entered under 1.9.6 of the Supplement to the EIAPP Certificate; and

.6 Section 2.2.1 of the Supplement to the IAPP Certificate shall be completed to identify which engines installed on a ship are approved to operate with multiple engine operational profiles.

8.3 Use of multiple engine operational profiles

8.3.1 An engine operational profile shall only be used in accordance with the associated conditions as given in the technical file.

8.3.2 The identification reference of the engine operational profile in use shall be recorded as part of the onboard NO_x verification procedure together with data that demonstrates that the conditions attached to the use of that engine operational profile were being complied with.

8.3.3 On change from one engine operational profile to another, the date and time of the completion of that change shall be recorded as part of the onboard NO_x verification procedure for that engine."

Appendix V – Parent engine test report and test data

11 The title of appendix V is replaced by the following:

"**Parent engine test report, test data, and determination of the highest composite specific emission value**"

12 Title of section 1 is replaced by the following:

"**Section 1 – Parent engine test report**
(see 5.10 and 8.2 of the Code)"

13 Title of section 2 is replaced by the following:

"**Section 2 – Parent engine test data to be included in the technical file, additionally, for marine diesel engines to which 8.1.1.3 applies, the relevant test data for all engine operational profiles for which the engine is certified which are to be included in the technical file** *(see 2.4.1.5 and 8.2 of the Code)*"

14 A new section 3 is added after existing section 2 as follows:

"**Section 3 – Multiple engine operational profile parent engine, determination of the composite specific emission value to be included in the technical file for engines with those multiple engine operational profiles**
(see 8.2 of the Code)

Calculation of the highest composite specific emission value in accordance with 8.2.3.3."

Appendix VII – Checklist for an engine parameter check method

15 In paragraph 1, at the end of sub-paragraph 1.14.1, "." is replaced with ";", and sub-paragraphs 1.15 to 1.17 are added after existing sub-paragraph 1.14 as follows:

"1.15 list of identification references of all engine operational profiles available for the engine and associated conditions, if applicable, under which each is to be used (see chapter 8);

1.16 list of auxiliary control devices accepted for the engine and the operating conditions under which those devices function;

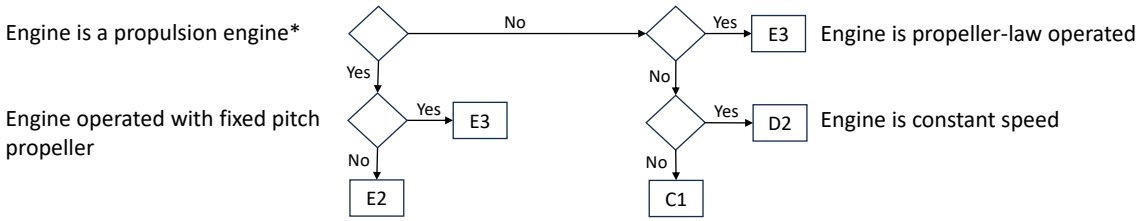
1.17 the engine power or engine load and speed boundaries within which the engine is certified to operate."

16 A new appendix IX is added as follows:

"**Appendix IX – Flow chart for engine certification test cycle determination**

(refer to 3.2 of the Code)

Test cycle selection flowchart



* A propulsion engine may additionally perform non-propulsion duties during or separately to propulsion duties. An engine that solely or in part provides athwartships movement of a ship is not a propulsion engine.

"

17 A new appendix X is added as follows:

"**Appendix X – Calculation of not to exceed emission limit value within not to exceed zone**

(refer to 5 of the Code)

1 This appendix describes the method for determining the not to exceed emission limit value, N_{Lz}, at any point within the not to exceed zone for comparison with a determined point emission value as set out in 3.3 of this Code.

2 Where engine test results are used to determine a point emission value, formula (1) shall be used to generate that value. At that point the tolerance requirements of 5.9.6.2 of this Code apply:

$$N_{Mn} = \frac{q_{mNOx}}{P_{Mn}} \quad (1)$$

where:

N_{Mn} = NO_x at the point *Mn* in g/kWh

P_{Mn} = Power at the point *Mn* (brake plus auxiliary) in kW

q_{mNOx} = Mass flow rate of NO_x in g/h – see 5.12.5.2 of this Code

q_{mNOx} is to be corrected for humidity and temperature consistent with the method used for the engine test from 5.12.4 of this Code.

3 Designation of not to exceed zone for E2, E3 and D2 test cycles in limit area of the not to exceed zone

3.1 The limit area of the not to exceed zone for engines certified to the E2 and E3 test cycles is defined by a speed boundary of equal to or greater than 63% and a power boundary of equal to or greater than 25%. The limit area of the not to exceed zone for the D2 cycle is defined by a power boundary of equal to or greater than 25%, at the nominal speed of the engine.

3.2 For the E3 and variable-speed application of the E2 cycle certified engines, the applicant is to define, in accordance with 3.3.1 of this Code, the not to exceed zone within the limit area of the not to exceed zone as wide or as narrow as applicable for their intended applications of the engine. The applicant-defined not to exceed zone shall encompass all normal steady-state speed load combinations within the limit area of the not to exceed zone for the applications of the engine.

3.3 The applicant's designated not to exceed zone can be defined by any mathematical formula(e), lists of coordinates or other method of defining the boundary. The not to exceed zone does not need to extend to the boundary of the limit area of the not to exceed zone.

3.4 For D2 and constant-speed E2 cycle certified engines, the not to exceed zone will be a line of power greater than 25% at the nominal speed.

4 Determination of not to exceed emission limit value for E2, E3 and D2 test cycles

4.1 The not to exceed emission limit value at each NO_x checkpoint shall be determined in accordance with the requirements of this section.

Note: if there is an auxiliary control device that causes a NO_x discontinuity within the not to exceed zone, follow the additional procedure in section 6 to insert proxy NO_x emission points to address the area(s) of discontinuity.

4.2 Interpolated NO_x value N_y at power P_y between mode points as determined using formula (2):

$$N_y = N_{Ma} + \left(P_y - P_{Ma}\right) \cdot \frac{(N_{Mb} - N_{Ma})}{(P_{Mb} - P_{Ma})} \quad (2)$$

where:

N_y = Interpolated NO_x value at power P_y

N_{Ma} = Measured point emission value according to formula (1) at nearest measured mode point at power below checkpoint power

N_{Mb} = Measured point emission value according to formula (1) at nearest measured mode point at power above checkpoint power

P_y = Power at checkpoint

P_{Ma} = Power at mode point below checkpoint

P_{Mb} = Power at mode point above checkpoint

4.3 Determine the not to exceed emission limit value at power P_y between the mode points, to the Tier, as applicable.

.1 For Tier II

The not to exceed emission limit value at power P_y is given by formula (3)

$$N_{Lv} = N_y \cdot 1.2 \quad (3)$$

where:

N_{Lv} = Not to exceed emission limit value at power P_y

N_y = Interpolated NO_x value at power P_y

.2 For Tier III

The not to exceed emission limit value, N_{Lv}, at power P_y shall be either set by 3.1.4 of this Code or as determined in accordance with formula (4), whichever is the lower.

N_{Lv} is the lower of N_{cap} or N_{LV},

with:

$$N_{LV}, = N_y + 0.25 \cdot N_{LC} \quad (4)$$

$$N_{cap} = 1.5 \cdot N_{LC} \quad (5)$$

where:

N_{LC} = NO_x cycle limit for engine

N_{Cap} = the maximum mode point value for the engine according to 3.1.4 of this Code

4.4 If the checkpoint power P_y is on the propeller law curve for an E3 certified engine or the nominal speed line for a constant-speed E2 or a D2 certified engine:

$$N_{Lz} = N_{Lv} \quad (6)$$

For this situation the determination of the not to exceed emission limit value, N_{Lz}, is complete for that checkpoint. Otherwise continue with 4.5.

4.5 For E3 and variable-speed application of the E2 cycle certified engines, where the checkpoint power P_y is located at a speed not on the line between the measured mode points, carry out the additional procedure in 4.5.1 to 4.5.4.

.1 Determine the NO_x limit at either edge of the not to exceed zone, N_{Le}, for the selected checkpoint power P_y along a line of constant power, in accordance with formula (7):

$$N_{Le} = N_y \cdot F_\beta \cdot 1.5 \quad (7)$$

with:

$$F_\beta = \frac{N_{LC}}{N_C} \quad (8)$$

where:

N_{Le} = NO_x limit at edge of not to exceed zone

N_{LC} = NO_x cycle limit for engine

N_C = NO_x specific emission value for the engine from 5.12.6.1 of this Code

.2 Determine the not to exceed emission limit value at a checkpoint power P_y which is on the constant power line between the mode point line and the edge of the not to exceed zone in accordance with formula (9):

$$N_{Lz\prime} = N_{Lv\prime} + (n_z - n_v) \cdot \frac{(N_{Le} - N_{Lv\prime})}{(n_e - n_v)} \quad (9)$$

with:

For tier II, $N_{Lv\prime} = N_{Lv}$ from formula (3)

For tier III, $N_{Lv\prime}$ is from formula (4)

where:

$N_{Lz\prime}$ = NO_x limit at required checkpoint

N_{Le} = NO_x limit at edge of not to exceed zone

n_z = Speed at required checkpoint

n_e = Speed at edge of applicants selected not to exceed zone at checkpoint power (may be on lower or higher side of mode line as required for value of n_z)

n_v = Speed on measured mode line at selected power

For engines certified to the E2 test cycle, the speed on the measured mode line, n_v, is the nominal speed

For engines certified to the E3 test cycle, the speed on the measured mode line, n_v, is determined by the cube law propeller curve:

$$n_v = n_{MCR} \cdot \sqrt[3]{\frac{P_y}{P_{MCR}}} \quad (10)$$

where:

n_{MCR} = Rated speed from 1.3.12 of this Code

P_y = Power at checkpoint

P_{MCR} = Rated power from 1.3.11 of this Code

.3 Determine the not to exceed emission limit value at power P_y as applicable:

.1 For Tier II

The NO_x limit is the interpolated result:

$$N_{Lz} = N_{Lz'} \quad (11)$$

.2 For Tier III

The not to exceed emission limit value at power P_y shall be set by 3.1.4 of this Code or as determined in accordance with 4.5.3.1 whichever is lower:

N_{Lz} is the lower of N_{cap} or $N_{Lz'}$

5 Determination of not to exceed emission limit value for the C1 test cycle

5.1 For the C1 test cycle within the limit area of the not to exceed zone, screening is conducted between the measured mode points of 100%, 75%, and 50% load at both intermediate speed (mode points 5, 6 and 7 respectively) and rated speed (mode points 1, 2 and 3 respectively).

This creates two zones, Zone A and Zone B, where double linear interpolation or extrapolation is carried out between the nearest mode points:

.1 Zone A uses mode points 5, 1, 6 and 2. Zone A may extend above the torque line from mode point 5 and mode point 1 or beyond the speed line from mode point 1 to mode point 5.

.2 Zone B uses mode points 6, 2, 7 and 3. Zone B may extend beyond the speed line from mode point 2 to mode point 3.

.3 The applicant may request that the Administration exclude operating points from the limit area of the not to exceed zone screening if the applicant can demonstrate that the engine is not capable of operating at steady state at those points when installed on a ship. Otherwise, the not to exceed zone consists of the entire limit area of the not to exceed zone.

5.2 Determine if the checkpoint is in Zone A or Zone B by determining if the checkpoint torque, T_z, is higher or lower than the torque on the boundary between Zone A and Zone B (75% load line) for the checkpoint speed.

$$T_v = T_{M6} + (n_z - n_I) \cdot \frac{(T_{M6} - T_{M2})}{(n_I - n_R)} \quad (12)$$

where:

T_v = Torque at checkpoint speed on a straight line between mode point 6 and mode point 2 (75% load line)

T_{M6} = Torque at mode point 6 (75% of torque at intermediate speed)

T_{M2} = Torque at mode point 2 (75% of torque at rated speed)

n_z = Checkpoint speed

n_I = Intermediate speed

n_R = Rated speed

5.3 Determine the interpolated/extrapolated NO_x value at desired checkpoint:

.1 If the checkpoint torque, T_z, is greater than T_v, use equation (13) and (14) for the interpolation or extrapolation.

$$N_z = N_u + (T_Z - T_u) \cdot \frac{(N_u - N_v)}{(T_u - T_v)} \quad (13)$$

with:

$$T_U = T_{M5} + (n_z - n_I) \cdot \frac{(T_{M5} - T_{M1})}{(n_I - n_R)} \quad (14)$$

where:

T_{M1} = Torque at mode point 1 (100% of torque at rated speed)
T_{M5} = Torque at mode point 5 (100% of torque at intermediate speed)

T_v = Torque at checkpoint speed on a straight line between mode point 6 and mode point 2 (75% load line) from formula (12)

T_u = Torque at checkpoint speed on a straight line between mode point 5 and mode point 1 (100% load line) from formula (14)

T_z = Torque at checkpoint

N_u = Interpolated NO_x at checkpoint speed on 100% load line

N_v = Interpolated NO_x at checkpoint speed on 75% load line

n_z = Checkpoint speed

n_I = Intermediate speed

n_R = Rated speed

.2 If the checkpoint torque, T_z, is less than T_v use equation (15) and (16) for the interpolation or extrapolation.

$$N_z = N_v + (T_Z - T_v) \cdot \frac{(N_v - N_w)}{(T_v - T_w)} \quad (15)$$

with:

$$T_w = T_{M7} + (n_z - n_I) \cdot \frac{(T_{M7} - T_{M3})}{(n_I - n_R)} \quad (16)$$

where:

T_{M3} = Torque at mode point 3 (50% of torque at rated speed)

T_{M7} = Torque at mode point 7 (50% of torque at intermediate speed)

T_v = Torque at checkpoint speed on a straight line between mode point 6 and mode point 2 (75% load line) from formula (12)

T_w = Torque at checkpoint speed on a straight line between mode point 7 and mode point 3 (50% load line) from formula (16)

T_z =Torque at checkpoint

N_v = Interpolated NO_x at checkpoint speed on 75% load line

N_w = Interpolated NO_x at checkpoint speed on 50% load line

n_z = Checkpoint speed

n_I = Intermediate speed

n_R = Rated speed

5.4 Determine the not to exceed emission limit value at checkpoint:

.1 For Tier II

The not to exceed emission limit value is given by formula (17):

$$N_{Lz} = N_z \cdot 1.2 \quad (17)$$

where:

N_{Lz} = Not to exceed emission limit value at checkpoint

N_z = Interpolated NO_x value at power P_z

.2 For Tier III
The not to exceed emission limit value shall be either set by 3.1.4 of this Code or as determined in accordance with 5.3, whichever is the lower:

N_{Lz} is the lower of N_{cap} or $N_{Lz'}$

with:

$$N_{Lz'} = N_z + 0.25 \cdot N_{LC} \quad (18)$$

$$N_{cap} = 1.5 \cdot N_{LC} \quad (19)$$

where:

N_z = Interpolated NO_x value at checkpoint

N_{LC} = NO_x cycle limit for engine

N_{Cap} = the maximum mode point value according to 3.1.4 of this Code

6 Method to address discontinuity in the operation zone due to an auxiliary control device

6.1 For each approved auxiliary control device, where there is operation in the not to exceed zone that causes a discontinuity in the NO_x emissions it can be necessary to introduce additional proxy mode points to account for the discontinuity in the area of engine operation where that auxiliary control device is active.

6.2 There will be two or more proxy mode points to cover the action of an auxiliary control device.

6.3 N_y is calculated in the same manner as 4.2 using the proxy points where necessary in the interpolation.

6.4 Use good engineering judgement that may include simulation or in-house testing to determine the appropriate NO_x level and location of the proxy points.

6.5 The engine power of the proxy mode points may overlap to account for hysteresis that may occur as a result of approaching the points from rising or falling power. The overlap should also take into account any variation in the operating point of the auxiliary control device based on engine speed.

6.6 Include the proxy mode points as part of the auxiliary control device documentation supplied to the Administration in the NO_x certification pack."

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