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PREVENTION AND RESPONSE
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Agenda item 11

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**DEVELOPMENT OF AMENDMENTS TO MARPOL ANNEX VI AND THE NO_x TECHNICAL
CODE ON THE USE OF MULTIPLE ENGINE OPERATIONAL PROFILES FOR A
MARINE DIESEL ENGINE**

Selection of test cycles

Submitted by IACS

SUMMARY

Executive summary: In order to facilitate discussions on the use of multiple Engine Operational Profiles, which are linked to the certification test cycles, and noting that the current MARPOL Annex VI and the NO_x Technical Code test cycle requirements do not adequately address application to variable-speed/variable-load engines used for main propulsion or ship power generation, this document proposes amendments to clarify test cycle application

*Strategic direction,
if applicable:* 2

Output: 2.15

Action to be taken: Paragraph 22

Related documents: MEPC 69/19/1; MEPC 73/11/1, MEPC 73/INF.15, MEPC 73/19; PPR 5/24; PPR 7/13/2 and PPR 7/18

Introduction

1 Norway proposed in document MEPC 69/19/1 a new output to develop guidelines for the use of more than one Engine Operational Profile (Map) in order to optimize the fuel consumption and the corresponding emission of engines, depending on the operational profile of ships. MEPC 73 agreed on the inclusion of a new output on "Development of amendments to MARPOL Annex VI and the NO_x Technical Code (NTC 2008) on the use of multiple engine operational profiles for a marine diesel engine" (MEPC 73/19, paragraph 15.18).

2 The Committee also agreed on the following scope of work for the output (MEPC 73/19, paragraph 15.18):

"Taking into account the concept of Not to Exceed (NTE) Zones, as described in documents MEPC 73/11/1 (United States) and MEPC 73/INF.15 (United States),

clarify whether multiple engine operational profiles are allowed, and if so, what regulatory controls should be applied, noting these may also need to include amendments to MARPOL Annex VI and the NO_x Technical Code 2008; and if not allowed, then what amendments would be necessary to MARPOL Annex VI and the NO_x Technical Code (NTC) 2008 to explicitly prohibit multiple engine operational profiles."

3 IACS notes that the subject output is linked to the certification test cycles prescribed in MARPOL Annex VI and the NTC 2008 and that matters relating to the difficulty of application of the existing test cycles to diesel-electric installations have previously been highlighted in document PPR 7/13/2 (Finland) and by IACS' efforts to further revise existing IACS UI MPC 51 (see document PPR 7/18).

4 Further, IACS notes that the increasing application of hybrid-powered vessels, Direct Current (DC) electric power technology and the introduction of variable-speed/variable-load engines used for propulsion and power generation creates new challenges for application of the existing test cycles.

5 In order to facilitate harmonized application of MARPOL Annex VI and the NTC 2008 with respect to applicable test cycles, IACS proposes amendments to the existing test cycle application scope to better cover the emerging range of engines applied to modern marine propulsion and power generation arrangements.

Background

6 Appendix II of MARPOL Annex VI and paragraph 3.2 of the NTC 2008 define the following test cycles, weighting factors and applications to be applied in the certification of marine diesel engines in accordance with regulation 13 of MARPOL Annex VI:

- .1 For constant-speed marine engines for ship main propulsion, including diesel-electric drive, test cycle E2 shall be applied;
- .2 For controllable-pitch propeller sets test cycle E2 shall be applied;
- .3 For propeller-law-operated main and propeller-law-operated auxiliary engines the test cycle E3 shall be applied;
- .4 For constant-speed auxiliary engines test cycle D2 shall be applied; and
- .5 For variable-speed, variable-load auxiliary engines, not included above, test cycle C1 shall be applied.

Table 1: Test cycle for "constant-speed main propulsion" application (including diesel-electric drive and all controllable-pitch propeller installations)

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

Table 2: Test cycle for "propeller-law-operated main and propeller-law-operated auxiliary engine" application

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

Table 3: Test cycle for "constant-speed auxiliary engine" application

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

Table 4: Test cycle for "variable-speed and variable-load auxiliary engine" application

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

Discussion

7 The above test cycles are derived from ISO 8178-4, "Reciprocating internal combustion engines – Exhaust emission measurement, Part 4: Steady-state and transient test cycles for different engine applications". IACS notes that the latest revision of this standard was published in 2020; MARPOL Annex VI and the NTC 2008 only apply steady state test cycles and only utilize some of the available test cycles and test cycle selection methodology given in ISO 8178-4.

8 With regard to the E3 test cycle, ISO 8178-4 recognizes that these engines are mainly operated slightly above or below their propeller curve.

9 IACS understands that engines used to drive electrical generators and operated solely according to the propeller law, for example, where applied to DC power generation systems, would be certified to the E3 test cycle, since these are by definition "propeller-law-operated auxiliary engines".

10 From the above test cycles IACS notes that diesel-electric applications are only referenced under the E2 test cycle and that the C1 test cycle is limited to auxiliary engine applications. This is limiting for the aforementioned variable-speed/variable-load engines that are optimized to deliver low fuel consumption in generator or propulsion applications and whose speed/torque operation points may, or may not, match E3 propeller curve or the C1 test cycle in operation.

11 IACS also notes that in ISO 8178-4:2007 the C1 test cycle was intended for "off-road vehicles, diesel powered off-road industrial equipment", and from ISO 8178-4:2017 it has been intended for "compression-ignition engine powered non-road machinery and industrial equipment", with some of the typical application examples including industrial drilling rigs, compressors, loaders, bulldozers, crawler tractors, forklifts, aerial lifts, mobile cranes and similar. It is the least applied of MARPOL Annex VI test cycles, but IACS members have

certified marine engines to the C1 test cycle where they are applied to variable-speed/variable-load applications, for example driving large pumping or compressor equipment. However, for many hybrid applications using variable-speed/variable-load engines, the existing C1 weighting factors may not be representative of the engine operational profile.

12 Criteria for the selection of the C1 test cycle intermediate speed is given in paragraph 3.2.8 of the NTC 2008, which are derived from and consistent with the criteria given in ISO 8178-4.

13 From ISO 8178-4, IACS further notes that the principle of test cycle standardization is to group applications with similar engine operating characteristics in order to reduce the number of test cycles to a minimum, but ensure that the test cycles are representative of actual engine operation. This is particularly relevant for the IMO test cycle regime, which is only steady state, and therefore the weighting factors provide the expected typical operational time at each part of the speed/load map, to provide representative real world cycle weighted emissions.

14 As per paragraph 4.3.10.5 of the NTC 2008, if an alternative standard or a different test cycle than that allowed by the NTC 2008 is to be applied, then the manufacturer must prove to the Administration that the weighted average NO_x emissions for the appropriate test cycles fall within the relevant limit values under regulation 13 of MARPOL Annex VI and the NTC 2008 before the Administration may issue an EIAPP certificate. IACS notes that there is no reference to ISO 8178-4 within this requirement, as a possible international standard, which is acceptable to the Organization (that may assist an Administration in assessing an alternative standard or different test cycle) and also that there are no guidelines in place to assist the manufacturer or the Administration in application of this.

Proposal

15 While it may take some time to fully conclude the discussions under this multiple Engine Operational profiles work item, IACS believes there is merit in an expedited amendment of MARPOL Annex VI and the NTC 2008 to facilitate harmonized application of the existing test cycle regimes for variable-speed/variable-load engines. On that basis, IACS proposes to expand the scope of the E3 and C1 test cycles to allow application to diesel-electric configurations, where variable-speed/variable-load engines may operate more closely with those speed/load curves, operating points and associated test cycles, as follows*:

.1 MARPOL Annex VI:

"Appendix II

**Test cycles and weighting factors
(regulation 13)**

...

.3 For propeller-law-operated main and propeller-law operated auxiliary engines, ~~including diesel-electric drive~~, the test cycle E3 shall be applied;

...

.5 For variable-speed, variable-load ~~auxiliary~~ engines, not included above, test cycle C1 shall be applied.

...

* Tracked changes are indicated using "strikeout" for deleted text and "grey shading" to highlight all modifications and new insertions, including deleted text.

Test cycle for *propeller-law-operated main* and *propeller-law-operated auxiliary engine* application (including diesel-electric drive)

...

Test cycle for *variable-speed and variable-load auxiliary engine* application...".

.2 NO_x Technical Code 2008:

"3.2.4 For propeller-law-operated main and propeller-law-operated auxiliary engines, including diesel-electric drive, test cycle E3 shall be applied in accordance with table 2.

Table 2
Test cycle for
"Propeller-law-operated main and propeller-law-operated auxiliary engine"
application (including diesel-electric installations)

...

3.2.6 For variable-speed, variable-load auxiliary engines not included above, test cycle C1 shall be applied in accordance with table 4.

Table 4
Test cycle for "Variable-speed, variable-load auxiliary engine" application."

Confirmation and further discussion

16 In addition to the above proposals, IACS seeks confirmation from the Sub-Committee regarding its understanding outlined in paragraph 9 above, that engines used to drive electrical generators and operated solely according to the propeller law would be certified to the E3 test cycle.

17 With regard to the suitability of the C1 weighting factors for variable-speed/variable-load power generation and propulsion applications identified in paragraph 11 above, IACS provides the following as one, of many possible, alternative weighting factors that may be applied to C1 applications depending on how the particular engine loading is controlled.

Test cycle	Speed	Rated				Intermediate			Idle
		Torque	100%	75%	50%	10%	100%	75%	
type C1b	Torque	100%	75%	50%	10%	100%	75%	50%	0%
	Weighting factor	0.05	0.25	0.20	0.05	0.05	0.20	0.15	0.05

18 Furthermore, IACS notes that ISO 8178-4 includes a D1 test cycle, which is intended to be applied to power plants, and is copied below for reference.

Test cycle	Speed	100%	100%	100%	
	type D1	Power	100%	75%	50%
		Weighting factor	0.3	0.5	0.2

19 Therefore, IACS invites the Sub-Committee to note some of the possible additional test cycles, or different weighting factors, that could be added to MARPOL Annex VI and the NTC 2008 to better cover the range of marine applications, and advise on a way forward.

20 With regard to the comments under paragraph 14 and application of paragraph 4.3.10.5 of the NTC 2008, IACS invites the Sub-Committee to consider whether an amendment to paragraph 4.3.10.5 of the NTC 2008, or the development of a unified interpretation, or the development of guidelines for application of alternative test cycles would benefit the harmonized application, and if so, to advise on a way forward.

21 Also, IACS invites the Sub-Committee to consider whether the Organization should invite the International Organization for Standardization (ISO) to advise on plans or to initiate work on updating ISO 8178-4 (as the source of MARPOL Annex VI and the NTC 2008 test cycles) to develop new test cycles appropriate for modern marine engines.

Action requested of the Sub-Committee

22 The Sub-Committee is invited to consider the information contained in this document, in particular the proposal in paragraph 15, and is invited to confirm and provide advice on the issues raised in paragraphs 16 to 21, and take action as appropriate.
