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POLLUTION PREVENTION AND RESPONSE

Application of more than one engine operational profile ("multi-Map") under the NOx Technical Code 2008

Submitted by IACS

SUMMARY

Executive summary:	This document provides further points of discussion to facilitate the Committee's consideration of the recommendation of PPR 4 that the use of multiple engine operational profiles (Maps) for marine diesel engines certified under MARPOL Annex VI and the NO_X Technical Code 2008 should be taken forward as a new output, taking into account the scope of the new output for use of multiple engine operational profiles (Maps) as agreed by the Sub-Committee
Strategic direction:	No related provisions
High-level action:	No related provisions
Output:	No related provisions
Action to be taken:	Paragraph 28
Related documents:	MEPC 69/19/1, MEPC 69/19/3, MEPC 69/19/4, MEPC 69/21; PPR 4/20, PPR 4/WP.6 and PPR 4/21

Background

1 PPR 4 recalled that MEPC 69, having considered document MEPC 69/19/1 (Norway), proposing the development of guidelines for the use of more than one engine operational profile (Map), together with commenting documents MEPC 69/19/3 (EUROMOT) and MEPC 69/19/4 (United States), had referred the proposal to PPR 4 for detailed consideration and advice, so that an informed decision with regard to the proposed new output could be taken at MEPC 71 (MEPC 69/21, paragraphs 19.6 and 19.7).

2 Having reviewed the report of the Working Group on Prevention of air pollution from ships (PPR 4/WP.6), PPR 4 agreed to recommend to the Committee that the "Development of amendments to MARPOL Annex VI and the NO_X Technical Code on the use of multiple engine operational profiles (Maps) for marine diesel engines" should be taken forward as a new

output. PPR 4 noted that the working group, following consideration, had agreed to the following draft definition for "Engine Operational Profile (Map)" for the purposes of the NO_X Technical Code 2008 (NTC 2008) (PPR 4/21, paragraphs 20.12 and 20.13):

> "The emission performance resulting from the application of a particular set of NO_X influencing settings as a function principally of engine speed and load as applied by an electronic engine management system. Those settings may relate to, but are not limited to, fuel injection, charge air/exhaust valve operation and charge air or exhaust bypass/wastegate controls. Variation from settings is only allowed using approved auxiliary control devices as defined in regulation 2.4 of MARPOL Annex VI."

It is recalled that an "auxiliary control device", according to regulation 2.4 of MARPOL Annex VI, is defined as follows:

> "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."

3 PPR 4 also agreed that further consideration of this issue should take into account the following scope of the new output for use of multiple engine operational profiles (Maps):

> "Consider whether multiple engine operational profiles (Maps) should be allowed, and if so, what regulatory controls should be applied, noting that these may also need to include amendments to MARPOL Annex VI and the NOx Technical Code 2008, and if not allowed, then what amendments would be necessary to MARPOL Annex VI and the NO_X Technical Code to explicitly prohibit multiple engine operational profiles (Maps)."

4 The working group at PPR 4 further agreed that further consideration of this issue should take into account questions on switching, and the frequency of switching, of Maps (PPR 4/WP.6, paragraph 35).

5 Finally, IACS considers it is important to recall that the working group at PPR 4 noted that, with regard to allowing multiple Maps to be utilized by marine diesel engines, it was recognized that the use of multiple Maps "should not be associated with allowing non-compliance with the provisions of regulation 13 of MARPOL Annex VI and the NO_X Technical Code" (PPR 4/WP.6, paragraph 35).

Discussion

6 In light of the above background information, IACS is of the view that the use of multiple engine operational profiles (Maps) for marine diesel engines should be further discussed by the Organization and offers the following points of discussion in support of the need for clarifications in the application of regulation 13 of MARPOL Annex VI and the NTC 2008.

Definitions of *engine operational profile (Map)*

7 To be more precise in terms of clarifying that it represents a "set of NO_X <u>influencing</u> settings", IACS believes that the draft definition of an Engine Operational Profile (Map) as developed by PPR4 could be improved as follows (additions/~~deletions~~):

"Engine Operational Profile (Map)" for the purposes of the NO_X Technical Code 2008 is ~~The emission performance resulting from the application of~~ a particular set of NO_X influencing settings as a function principally of engine speed and load as applied by an electronic engine management system. Those settings may relate to, but are not limited to, fuel injection, charge air/exhaust valve operation and charge air or exhaust bypass/wastegate and SCR bypass controls. Variation from settings is only allowed using approved auxiliary control devices as defined in regulation 2.4 of MARPOL Annex VI."

Engine NO_X certification in accordance with the NTC 2008

8 The engine group concept is a fundamental feature of the NTC 2008. This allows options on NO_X critical components and settings/operating values, provided that any of the combinations in which those options would be used, as stipulated in the technical file, do not result in a NO_X emission value which exceeds the limit value. The selected parent engine being the engine with the particular given combination of options which results in the highest NO_X emission value.

9 Hence, to take the "Map Sea/Map Harbour" example as given in figure 1 of document MEPC 69/19/1, it would be in accordance with the NTC 2008 for there to be, for example, particular "At Sea" and "At Harbour" fuel injection nozzles. This could be equally applied to a number of other NO_X critical components and settings.

10 Paragraph 4.3.6 of the NTC 2008 states:

> 4.3.6 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.

IACS suggests that multiple Maps might be interpreted as an "adjustable feature".

11 Where the parameter check method is used as the NO_X on-board verification procedure, then each change of any NO_X critical component or setting, as identified in the engine's approved technical file, is to be entered into the record book of engine parameters. This would apply equally to electronic Maps as it does for the more typical mechanical components such as fuel injection nozzles.

Electronic fuel injection control

12 With the application of electronically controlled fuel injection systems, engine designers have been significantly freed from the physical constraints imposed by a mechanical system whereby the profile of the fuel cam and the profile of the fuel pump control edges defined performance. Electronic control potentially allows selection of both the starting and duration/end of injection together with rail pressure control and furthermore can be combined with injector switching and inlet/exhaust valve timing and other controls.

13 Consequently, for a given engine frame and running gear, quite different performance characteristics can be obtained with multi-Map; those performance characteristics may include, but not limited to, specific fuel oil consumption and CO_2 emissions, NO_X emissions or visible smoke. A further driver would be where selective catalytic reduction (SCR) control is fitted and there is the need to maintain the required exhaust gas minimum temperature at SCR inlet.

14 The key point with electronic control is that unlike with a mechanical system, performance, however defined, at one load point is not necessarily constrained by the performance at adjacent (higher and lower) load points. For example – for a conventional, mechanically controlled, constant speed generator driving engine, if the "performance" is known at, say 84% and 86% loads then the performance at 85% load could be confidently predicted in the absence of any discontinuous control arrangements such as variable injection timing. That is not automatically the case with electronically controlled engines where very different injection and valve control settings could be applied between adjacent load points. If the consequence of this approach is to significantly increase the emissions between test points, IACS understands this may well be considered as an "Irrational emission control strategy" (as defined in regulation 2.13 of MARPOL Annex VI):

> "13 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."

15 For engines with electronic fuel injection control certified in accordance with the NTC 2008, the applied Map is a set of NO_X critical settings covering injection timing, injection time/period and fuel rail pressure. The typical requirement is that the Map data are to be capable of being displayed and recorded with specified codes or/and identification numbers in order that it can be verified at surveys and PSC inspections. While the engine builder commits not to alter that Map without approval of the recognized organization (RO), the RO typically holds no detailed information as to the actual content of the Map itself as applied other than the observed engine performance at the test cycle(s) mode points.

Application of a multi-Map

16 Given the flexibility provided by electronic fuel injection control it can be seen that there would be demands for more than one Map option to be supplied in those instances where it is envisaged that an engine will not operate according to a single operating mode. Each Map being optimised for operation focused at a particular operating mode. Hence the concept of the "multi-Map".

17 There are a wide range of instances where a multi-Map may be appropriately discussed:

.1 engines with SCR – a Map with SCR in operation, a Map with SCR shut-down;

.2 engines with other post-combustion treatment devices – a Map with device in operation, a Map with device shut down;

.3 engines operated inside/outside ECA-SO_X – a Map on distillate fuel oil, a Map on residual fuel oil (on the basis of using different fuel types inside and outside ECA-SO_X);

.4 engines operated on emulsified fuel (or other water adding systems) – a Map with system in operation, a Map with system not in operation;

.5 main engines – a Map on loaded passage, a Map on ballast passage;

.6 tugs – a Map for towing, a Map for free running;

.7 ro-ro passenger ship main engines – a Map on day passage (fast), a Map on night passage (slow); and

.8 low NO_X emission mode when a ship is calling at port to reduce port fees.

The above Maps are some of the possible examples. Combinations of Maps of the above examples are also possible.

18 In cases paragraphs 17.1 to 17.6 and 17.8, there is a specific "outside" factor which governs which of the two Maps is to be applied; whereas in paragraph 17.7 it is the intended engine loading that is the deciding factor and the engine in service will operate over a portion of the range of each Map. Where there is more than one Map option the change from one Map to another may be initiated by an outside action – such as starting up/shutting down the SCR – or it could be automatic.

Specific considerations related to multi-Maps under the NTC 2008

19 As highlighted in the previous section, multiple "Maps" may be applied for a variety of operating reasons based on the understanding that the situation is in principle no different from any other NO_X critical option as provided for in the NTC 2008 – in all cases each combination of options is to result in cycle with a weighted NO_X emission value that does not exceed the relevant limit value.

20 Consequently, in proposing an engine group incorporating a multi-Map the applicant would be required to produce emission test reports that give the emission performance for each Map over the whole of the test cycle(s) for which the engine is to be certified. That Map, in combination with any other relevant NO_X critical component or setting options, that results in the highest NO_X emission value would be selected as the set-up to be used for the parent engine emission testing.

21 An issue in the case of different Map options is the number of options which could be available and the ease with which they can be changed. This is in contrast to the given example in paragraph 9 of different fuel nozzle options – in order to change from one type to the other clearly the engine has to be stopped, all injector units disconnected and removed and the other nozzle option fitted. The stopping of the engine and the significant time and effort expended to make that change, therefore naturally restricts both the number of available options that would be offered by the engine builder and the frequency of their application by the user.

NOx emission limits under the NTC 2008

22 The core point of document MEPC 69/19/4 was that a multi-Map increases NO_X emissions when the engine operates in higher NO_X emission Maps through Map shifts on different load points.

23 In the discussion on multi-Maps the principle remains that each "Map" must result in an emission value which does not exceed the limit value. Additionally, in respect of Tier III NO_X certification, the individual mode point values are not to exceed the overall emission limit value by more than 50% (except some low load points specified in paragraph 3.1.4 of the NTC 2008).

24 There is no MARPOL Annex VI or NTC 2008 requirement that the emission rate at a particular load is not above the applicable NO_X emission limit value; and since the engine's value is a weighted average, there may be values which are above, as well as below, that determined value. On this basis, it is understood that individual mode point values can be above the limit value and the engine will remain "compliant"; the only restriction being the degree of that exceedance for Tier III NO_X engines.

"Defeat devices" and "irrational emission control strategies" in the context of multi-Maps

25 The 2008 revision of MARPOL Annex VI introduced the concepts of a "defeat device" and an "irrational control strategy", which are prohibited by regulation 13.9 and respectively defined in regulation 2.6, as stated below, and regulation 2.13 (see paragraph 14 above):

> "2.6 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."

26 In the case of marine diesel engines, since each Map to be used in a particular multi-Map option is to be tested across the whole of the applicable test cycle(s) for which the engine is to be certified; the question is whether a system which enables the use of only a portion of each Map in service, is to be considered a "defeat device" or an "irrational emission control strategy", or neither of them.

27 It is noted that the use of more than one Map in some cases is necessary for the proper working of the engine, while in other cases the use of more than one Map is considered in terms of improving an engine's performance, fuel consumption and CO_2 emissions.

Action requested of the Committee

28 The Committee is invited to note the information provided above in its policy consideration of the recommendation of PPR 4 that the "Development of amendments to MARPOL Annex VI and the NO_X Technical Code on the use of multiple engine operational profiles (Maps) for marine diesel engines" should be taken forward as a new output.