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AIR POLLUTION PREVENTION

Perceived shortcomings of regulation 13 of MARPOL Annex VI NO_x emission air pollution reduction programme

Submitted by Belgium, Canada, Denmark, Germany, Ireland, Netherlands (Kingdom of the), Norway and United States

SUMMARY

Executive summary:	This document outlines growing concerns that the regulation 13 NO_x emission control programme, and the NO_x ECA requirements in particular, are not achieving the anticipated reductions in air pollution from marine diesel engines. In addition, the document describes the effects of which continue to be worrisome given the dangerous human health and environmental impacts of these emissions.
Strategic direction, if applicable:	2
Output:	2.15
Action to be taken:	Paragraph 23
Related documents:	MEPC 80/5/1, MEPC 80/17; MEPC 81/11, MEPC 81/11/1, MEPC 81/INF.7; PPR 11/INF.2/Rev.1 and PPR 11/INF.4

Introduction

1 There is a growing concern among many Member States that the regulation 13 NO_x emission control programme, as revised in the 2008 amendments to MARPOL Annex VI, is not delivering the expected emission reductions and associated improvements in air quality. This concern was brought to the attention of the Committee through document MEPC 80/5/1 (Canada), which shared the results of a study that showed ships are not meeting the regulation 13 NO_x limits, with a focus on operation at low load. This document suggested various ways to address this issue, including additional test cycles or modification to the existing test cycles. This document responds to the invite by the Committee for interested Member States and others to provide any relevant information on in-service engine NO_x emission measurement campaigns, including findings from recent studies (MEPC 80/17, paragraph 5.35).

Background

2 This Committee has long been committed to reducing NO_x emissions from ships. As was abundantly explained in the discussions leading to the 2008 MARPOL Annex VI amendments and each of the NO_x ECA designations, these emissions have significant impacts on human health and the environment. NO_x is a precursor to ground-level ozone, which is formed by the reaction of volatile organic compounds and NO_x in the atmosphere in the presence of heat and sunlight. Ozone-related health effects include lung function decrements, respiratory symptoms, aggravation of asthma, increased hospital and emergency room visits, increased asthma medication usage, and a variety of other respiratory effects. NO_x is also a source of secondary particulate matter (PM) that is formed through atmospheric chemical reactions. Short-term exposure to PM (hours to days) is associated with premature mortality, aggravation of heart and lung disease (as indicated by increased hospital admissions and emergency department visits), increased respiratory symptoms including cough and difficulty breathing, changes in lung function, changes in heart rate rhythm, and other more subtle indicators of cardiovascular health. Long-term exposure is associated with mortality from cardiopulmonary disease and lung cancer, and effects on the respiratory system such as decreased lung function or increased respiratory disease. Finally, exposure to NO_x alone is linked to respiratory symptoms and hospital admissions. In addition to these significant human health impacts, NO_x emissions have important environmental impacts. NO_x emissions from ships adversely impact sensitive terrestrial and aquatic ecosystems, including areas of natural productivity, critical habitats, and areas of cultural and scientific significance.

3 The contribution of international shipping to national NO_x emission inventories can be significant. In Europe, shipping can contribute as much as 37.6% of total NO_x emissions of the EEAA-32 countries.[1] In the United States, in 2022, commercial shipping contributed 2.9% of the total national NO_x inventory (all sources), and 5.8% of the national mobile source NO_x inventory.[2] Canada estimates that international and domestic shipping combined represents 14.9% relative to the total NO_x emissions released in Canada from all sources in 2021, which has grown from just 6.6% in 2000.[3]

4 Recognizing that the contribution of shipping to NO_x emission inventories was expected to significantly increase as international shipping increased, the 2008 amendments to MARPOL Annex VI included new NO_x emission limits that were intended to address the high contribution of ships to global NO_x and ozone pollution throughout the world. A geographic approach was adopted, in which more stringent Tier III NO_x limits, set at 80% below the Tier I limit, would apply to engines above 130 kW while operated in designated NO_x Emission Control Areas (NO_x ECAs), beginning in 2016. In all other areas, the Tier II NO_x limits, set at 20% below the Tier I limit, apply to engines on ships built beginning in 2011.

5 This geographic approach was adopted because it would achieve nominal emission reductions globally while providing greater emission reductions for those areas with more significant air pollution concerns. In addition, this approach reflected the types of control technologies that were expected to be used to reduce NO_x emissions. Specifically, the Tier II 20% NO_x reduction was expected to be met through engine-based changes, such as fuel injection timing and air handling. In principle, these controls would function at all times.

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1 See Matthais, Voker, et al., "Shipping emissions contributions to the Mediterranean, North/Baltic Seas as well as selected regions in Asia" available at: https://www.scipper-project.eu/wp-content/uploads/2023/02/scipper-d4.3_s.pdf à Fig. 23; and (https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-5); EEA-32 includes (EU-15 + EU-10 + EFTA-4 + Romania, Bulgaria, Turkey).

2 See EPA National and State Tier 1 CAPS Trends by Tier 1 and EIS Sector for 2002 to 2022 at https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data (accessed 1/4/24).

3 See document MEPC 81/INF.7 (Canada).

The Tier III 80% NO_x reduction was expected to be met largely through the use of Selective Catalytic Reduction (SCR), or operation on LNG fuel and possibly also with Exhaust Gas Recirculation (EGR). These NO_x reducing technologies are on/off technologies that allow ships to turn the NO_x emission control system off when not operating in an ECA, reducing the overall cost of the programme. All of these technologies have low load considerations that require disabling the emission control system below a certain exhaust gas temperature or engine load.

Growing concern about the NO_x emission limits

6 There are currently four designated NO_x ECAs, with different effective dates.[4] The North American NO_x ECA covers portions of the United States, Canada and certain French territories; the Tier III NO_x limits apply to engines on ships with a keel laying date of 1 January 2016 or later. That date also applies for the United States Caribbean Sea NO_x ECA. For the Baltic Sea and North Sea NO_x ECAs, the Tier III NO_x limits apply to ships with a keel laying date of 1 January 2021 or later. Two additional NO_x ECAs are under consideration, covering the Norwegian Sea (MEPC 81/11/1 (Norway)) and Canadian Arctic waters (MEPC 81/11 (Canada)).

7 A sufficient amount of time has passed to allow NO_x ECA countries to assess the effectiveness of the programme. Submittals to MEPC and PPR describe these assessments: documents MEPC 80/5/1 (Canada), MEPC 81/INF.7 (Canada), PPR 11/INF.2/Rev.1 (Belgium et al.) and PPR 11/INF.4 (United States).

8 In document MEPC 80/5/1, Canada provides the results of a study regarding NO_x emissions from Tier III engines in ECAs to understand the effect of low-load operation on the performance of NO_x Tier III technologies. Ship speeds and load distributions were determined using Environment and Climate Change Canada's (ECCCs) Marine Emissions Inventory Tool (MEIT) and from Automatic Identification System (AIS) data. MEIT data was used to determine load distribution of all ships transiting Canadian waters around the Port of Vancouver in 2019 and AIS data was used to determine speed information for a small subset of ships for comparison purposes. The load distributions derived from this data did not produce load distributions consistent with the current understanding of ship operation. While a more robust analysis would be needed to verify the derived loads, these data suggest that ships spend between 25% and 35% of their operational time below 25% engine load where NO_x emission reduction technology may be completely disengaged or operating inefficiently. This finding indicates that the standard NO_x engine test cycle modal emission weighting factors may not adequately address emissions occurring at less than 25% power and is failing to control emissions below 25% power, as that operating mode is the lowest power point on the E2 and E3 test cycles and the 10% power points on the D2 and C1 (10% load) test cycles are exempt from the mode cap of 1.5 times the NO_x standard.

9 In document MEPC 81/INF.7, Canada shares the information on the number of Tier III ship calls to Canada to date and impacts of NO_x Tier III standards in Canadian waters. Canada's air quality modelling work indicates that implementation of the NO_x Tier III standards would help to reduce NO_2, O_3 and $PM_{2.5}$ emissions and improve air quality in coastal areas and near port cities in Canada. However, due to the slower-than-expected incidence of Tier III ship calls to Canada, Canada has not seen the benefits of the expected NO_x emission reduction in the North American ECA submission.

4 While the Tier III NO_x limits were originally intended to apply beginning in 2016 for all ECAs, no matter when they are designated, this approach was changed by the Committee in 2014. See document MEPC 66/21, paragraphs 6.25 to 6.39.

10 In document PPR 11/INF.2/Rev.1, Belgium et al. present a review of various studies that evaluated emission compliance based on remote NO_x emissions measurement campaigns carried out in the North Sea and Baltic Sea ECAs. Analyses were performed on data from drone-based measurements, fixed monitoring stations, helicopter-borne measurements, ship emission inventories, and remote sniffer and fixed sniffer station measurements. Only one third of NO_x emission from Tier III compliant ships in the ECA were found to be within the emission limits, and more than 50% of observed Tier III ships exceeded the Tier II emission limits. The uptake of Tier III ships was found to be slow due to the keel laid date. Only 21% of ships larger than 5,000 GT built in 2021 and 2022 had a keel laid date in or after 2021 and were certified as Tier III, meaning many recently built ships operating in the North Sea and Baltic Sea ECAs do not meet Tier III standards. Other findings indicate that ships often operate at low loads in and near coastal areas. The studies state that applicable test cycles do not secure low NO_x emissions for engine operating conditions below 25% load and weighting factors applied to mode points are biased toward higher loads. They also found that SCR technology is likely to be disengaged at low loads due to low exhaust gas temperatures. These findings indicate that current maritime NO_x legislation, in particular in ECAs to reduce NO_x emissions, lacks in effectiveness.

11 In document PPR 11/INF.4, the United States examines Tier III ECA compliance based on the nature of the fleet that entered the United States in 2015 and 2021 and how those ships were operated in 2021. Fleet turnover analysis shows that most ships built beginning in 2016 have keel lay dates in 2015 and are therefore not Tier III compliant. Ship operation analysis for 2021 shows that approximately 38% of Tier III engine operation was below 25% load, where SCR is likely to be disengaged due to low exhaust gas temperature; there is also a cost incentive to disengage NO_x emission controls as a consumable reductant, typically urea, is used. These two factors mean that the expected ECA NO_x emission reductions have not been realized. This contrasts with the ECA SO_x limits; where two studies find very good compliance in part due to the fuel sulphur limits applying to all ships, all at once, and were not phased in based on keel laying date.

Discussion

12 Taken together, the above assessments show that the NO_x ECA standards are not achieving the desired NO_x reductions, for three reasons: first, the combination of the marine engine test cycle and the MARPOL Annex VI and NTC auxiliary control device (ACD) could result in disabling Tier III NO_x technology at low loads, leading to little or no NO_x reductions in an ECA; second, the keel laying dates incentivize behavior to avoid compliance with the Tier III NO_x limits altogether; and third, there are challenges in linking compliance procedures to the real-world operational load-behavior of marine engines.

13 **Marine test cycles.** While the marine test cycles are intended to reflect real-world ship operating conditions, the weighting factors suggest that most operation is expected to occur between 75% and 100% power (combined weighting of 70% for the E2 and E3 test cycles), with almost no operation occurring below 25% power. In addition, MARPOL Annex VI and the NO_x Technical Code allow for the engine and/or its ancillary equipment (including the SCR system) to be protected against operating conditions that could result in damage or failure, through the use of an approved auxiliary control device (ACD). ACDs are set to disengage the SCR unit when the power drops below 25% power or when the exhaust temperature is too low to allow its operation (for example, < 300°C). This engine operation condition is typical in port entries, ports and even in coastal areas. Although engine temperatures may be high enough to extend the operation of the SCR system below 25% power, some engine manufacturers may choose that limit because the certification test cycles do not test engine emissions below 25% power; thus, NO_x reduction ceases below this point.

14 The assessments described above show that real-world ship operations within ECAs are often at loads lower than 25%. This means the SCR is not engaged, due to low exhaust temperatures, and the engines are not achieving the expected 80% emission reduction. Many technologies are available which could be used to maintain exhaust gas temperature and extend the operating range of NO_x emission reduction technologies below 25% power. These technologies include changes to charge air cooling strategies, SCR catalyst location, use of fuel with lower sulphur content, cylinder deactivation, fuel post injection, and heated urea dosers to name a few. In sum, the current structure of the certification test cycles has resulted in Tier III engines being certified that allow the SCR unit to be disabled below 25% power, even though the SCR unit may be capable of operating below that power point. Disabling SCR at low power means the ship operator does not need to use reductant during that operation.

15 Low-speed operation also affects the operation of Exhaust Gas Recirculation (EGR) system emission control. A review of EGR equipped engine technical files reveals that the EGR system is typically turned off via an ACD at low load. This operational load limit is necessary because the engine is supplied with less oxygen from the turbocharger at low load. This, in combination with the recirculated exhaust gas, leads to incomplete combustion. There is also a large time delay in the measurement of the oxygen content in the scavenge air receiver, which adversely affects combustion and smoke control. Thus, the EGR system is disengaged to prevent damage to the EGR and engine components.

16 In addition, there are reasons to believe that the same types of concerns extend to the Tier II programme, and those standards may not be achieving their intended reductions. For example, the test cycle limitations described above also apply to Tier II engines, which may experience much higher emissions at low load operation.

17 **Tier avoidance.** As noted above, both the Tier II and the Tier III NO_x limits are tied to the date a ship's keel is laid. When the standards were adopted, this was not expected to be a problem because the limits were originally designed to be retroactive, meaning that engines installed on ships built beginning in 2016 would be required to meet the Tier III limits while operating in any NO_x ECA designated in the future. This approach was intended to encourage owners to install Tier III-compliant technology on ships built beginning 2016 if they expected to operate those ships in ECAs designated at any time in the future (for example, in North America, Europe or Asia), or provide room for the installation of such technology in the future. It was expected that most ship builders would install the technology on ships expected to be used in North America, Europe, or Asia. The ship operators would only use the Tier III technology in a designated ECA; however, outside an ECA it could be disengaged.

18 When the North American ECA was adopted, there was some concern that shipowners would forego building Tier III-compliant ships, choosing instead to send their older ships to the United States and Canada. While that behaviour occurred, it was to a lesser extent than expected. Instead, shipyards took advantage of compliance being tied to keel laying to lay massive numbers of keels in 2015 to avoid having to install Tier III engines in ships built beginning in 2016. This is shown in documents PPR 11/INF.4 and MEPC 81/INF.7. These old, 2015 keels were being used to build new ships as late as 2022 and after. A similar effect is being seen for 2020 keels to avoid the Tier III standards in the Baltic and North Sea NO_x ECAs. It should be noted that in their proposal for a Norwegian Sea ECA, the co-sponsors request Annex VI be amended to include a new definition of keel laying date solely for that prospective ECA.

19 Compounding the problem, in 2014, well after designation and entry into force of the North American ECA in 2011 but before the Tier III NO_x effective date, Annex VI was amended in a way that significantly affected the structure of the NO_x requirements. While the effective date for the North American and United States Caribbean Sea ECAs would remain 2016, the effective date for future ECAs would be based to the "the date of adoption of [the future] emission control area, or a later date as may be specified in the amendment designating the

NO_x Tier III emission control area, whichever is later." As a result, ships built beginning in 2016 that did not expect to operate in a future NO_x ECA (e.g., in Europe) were not equipped with Tier III engines. Such a ship would be restricted from operating in only the North American and United States Caribbean Sea NO_x ECAs. A ship with a keel laid before the effective date of the Baltic and North Sea NO_x ECAs, or any future ECA, may forever operate in those ECAs without restriction. In sum, the combination of keel laying date and deferred compliance dates means that newly built ships can avoid the Tier III NO_x limits for a considerable period of time.

20 **Compliance procedures.** To demonstrate compliance with regulation 13 NO_x limits, a ship must show that each engine at or above 130 kW installed onboard achieves the standards, as evidence by an Engine International Air Pollution Prevention (EIAPP) certificate. When the Annex was first adopted, in 1997, this approach was reasonable because the standards were engine-based and it would be difficult (although not impossible) for the ship operator to take the engine out of compliance to, for example, improve fuel consumption. While continuous emission monitoring was considered during the discussions of the 2008 amendments, the final programme continued the certificate-based approach, although adding a requirement to record Tier III operating condition in the record book of engine parameters. Unfortunately, this approach has proven to be quite ineffective, as port State control officers are often limited to paperwork inspections to verify compliance even in those cases where there are reasons to believe there was non-compliance based on remote sensing or other information. This weak compliance approach can motivate emission violations, especially if the violation cannot be detected through paperwork. Tier II engines are also limited to paperwork compliance, even though modern electronically controlled engines can also be adjusted just by another engine operational profile to fall out of compliance. In sum, shortfalls in the compliance procedures means that it is difficult to detect possible violations by ships that are equipped with Tier III, and/or even Tier II engines and their NO_x reduction technology, even in cases where high NO_x emissions are observed through remote sensing.

21 **Alternative fuels.** It is important to address these concerns even as the international marine transportation sector moves to zero and near-zero carbon fuels. The use of alternative fuels, which is expected to be the main compliance method for achieving the Chapter 4 greenhouse gas reductions, may not always reduce NO_x emissions. At least some alternative fuels (fatty acid methyl ester (FAME) biodiesel, methanol, hydrogen, and ammonia) may have different NO_x emissions than marine diesel fuel, which could affect compliance with both the Tier II and Tier III standards. Also, nitrous oxide (N_2O), which is a by-product of combustion, is generally recognized as having much greater global warming potential than CO_2, and its emission can be adversely affected by improperly designed NO_x reduction technologies.

Conclusion

22 As shown by the recent assessments of the NO_x ECAs, there are serious concerns with the effectiveness of the regulation 13 NO_x control programme to achieve the intended air pollution reductions from marine diesel engines. As a result, large populations who live or work near ports and coastal areas continue to be exposed to very high levels of NO_x and experience adverse health effects. In addition, sensitive ecosystems continue to be damaged. It is recommended the Committee consider the information set out in this document, including documents referenced in it, to examine the shortcomings of the current NO_x control programme in regulation 13 of MARPOL Annex VI and consider a way forward to ensure the NO_x control programme provides cleaner air and the protections and health benefits for the affected populations of the current as well as future NO_x ECAs envisaged when the programme was created.

Action requested of the Committee

23 The Committee is invited to consider the proposals and information contained in this document, and to take action, as appropriate.

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