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PREVENTION OF AIR POLLUTION FROM SHIPS

Revision of the NOx Technical Code
Tiers 2 emission limits for diesel marine engines at or above 130 kW

Submitted by the United States

SUMMARY

Executive summary:	This paper outlines the views of the United States on the need for establishing a second tier of emission limits for marine diesel engines above 130 kW.
Action to be taken:	Paragraph 16
Related documents:	MP/CONF.3/35

Background

1 On September 26, 1997, the Parties to the International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto (MARPOL 73/78) adopted a new Annex VI to the Convention, Regulations for the Prevention of Air Pollution from Ships (1997 Protocol). Regulation 13 of the 1997 Protocol sets out emission limits for emissions of nitrogen oxides (NOx) from marine diesel engines. According to Regulation 13, the NOx emissions of any diesel engine with a power output of more than 130 kW installed on a ship constructed on or after 1 January 2000, or that undergoes a major conversion on or after that date, cannot exceed the following limits: **

(i)	17.0g/kWh	when *n* is less than 130 rpm
(ii)	$45.0*n^{(-0.2)}$ g/kWh	when *n* is 130 or more but less than 2000 rpm
(iii)	9.8 g/kWh	when *n* is 2000 rpm or more
		where *n* = rated engine speed (crankshaft revolutions per minute).

**See Figure 1. at the annex of this paper for a graphical representation of this engine speed (rpm) to NOx emissions relationship.

2 At the September 26, 1997, Diplomatic Conference, many Member States expressed concern that these NOx limits would not result in the emissions reductions they were intended to achieve. The Member States, through the MEPC, had set out in the early 1990s to achieve a 30 percent reduction in NOx emissions from these engines. However, newly available test data suggested that NOx levels from marine diesel engines were already at or close to the agreed-upon standards. Several delegations were concerned about this shortfall, and expressed the desire to provide for a review of these emission limits with the aim of proscribing more stringent limits, taking into account the adverse effects of such emissions on the environment and any technological developments in marine engines. Through Conference Resolution 3, also adopted on September 27, 1997, the Parties invited the MEPC to review the NOx emission limits at a minimum of five-year intervals after entry into force of the 1997 Protocol and, if appropriate, amend the NOx limits to reflect more stringent controls.

3 While the Annex has not yet gone into force, it is believed that owners of ships that operate internationally will begin to comply with the Regulation 13 NOx limits beginning 1 January 2000. This is because ships that operate internationally will be required to demonstrate compliance with Regulation 13 when their owners seek to obtain an International Air Pollution Prevention Certificate after entry into force. Owners of ships that do not operate internationally may be exempted from the Regulation 13 NOx emission limit requirements prior to entry into force of the 1997 Protocol if the relevant Administration allows such exclusion pursuant to Regulation 13(1)(c).

4 Because of continuing concern about the contribution of marine diesel engines to both local and international air quality, the United States submits the following information and related recommendations for consideration by the Committee.

Health and environmental effects associated with NOx emissions

5 NOx emissions from marine diesel engines are of concern to the international community primarily due to their contribution to ground level ozone. Ground level ozone is formed when hydrocarbons and oxides of nitrogen react in the presence of sunlight. Over the past few decades, many researchers have investigated the health effects associated with both short-term (one- to three-hour) and prolonged acute (six- to eight-hour) exposures to ozone. Numerous controlled-exposure studies of moderately exercising human subjects, as well as field and epidemiological studies, provide evidence of associations between short-term and prolonged acute ozone exposures and health effects ranging from respiratory symptoms and lung function decrements to increased hospital admissions for respiratory causes. In addition to these health effects, daily mortality studies have suggested a possible association between ambient ozone levels and an increased risk of premature death.

6 In addition to human health effects, ozone is known to adversely affect the environment in many ways. These effects include reduced yield for commodity crops, for fruits and vegetables, and commercial forests; ecosystem and vegetation effects in such areas as National Parks; damage to urban grass, flowers, shrubs, and trees; reduced yield in tree seedlings and non-commercial forests; increased susceptibility of plants to pests; materials damage; and reduced visibility. Nitrogen oxides (NOx), key precursors to ozone, also result in nitrogen deposition into sensitive nitrogen-saturated coastal estuaries and ecosystems, causing increased growth of algae and other plants.

7 Finally, there is growing concern that ship emissions of NOx and HC may be associated with global climate change. Although these pollutants are not among the direct greenhouse gases of primary concern to the United Nations Framework Convention on Climate Change (UNFCCC), NOx is an ozone precursor that may interact with hydrocarbons (HC) to increase the production of ozone, which is a greenhouse gas. While the contribution of ships to global HC emissions are much lower than other pollutants, some researchers have suggested that the effect of these HC emissions may be notable, particularly in the remote ocean where significant NOx emissions from ships make ozone production "HC limited" (i.e., the amount of HC emitted may effectively cap the potential for ozone formation in remote locations). Research is currently underway to better define how tropospheric ozone formation may contribute to global warming and how ship-generated NOx, as well as HC, emissions may affect this scenario.

Inventory impacts of marine diesel engines and expected regulation 13 NOx reductions

8 At the time the Regulation 13 emission limits were drafted, NOx emissions from marine diesel engines were not well understood and the international community had actual emissions data from only a very few engines on which to base the standards. Since that time, more engine emission data has become available for all sizes of marine diesel engines, including a test program carried out by Lloyds Register, as well as various marine engine manufacturers.[1]

9 Some studies estimate the total contribution of marine diesel engines to NOx inventories at 4 percent or higher. A recent study by Corbett and Fischbeck estimates that these engines may contribute as much as 14 percent of world-wide nitrogen emissions from fossil fuels annually.[2] This is as much as 42 percent of the annual NOx emissions of North America, 50 percent of the annual NOx emissions of the United States, and 74 percent of the annual NOx emissions of OECD Europe. As illustrated in Table 1, below, the majority of these emissions, approximately 64 percent, are from bulk cargo and general cargo ships.

Table 1
World Marine Nitrogen Emissions, by Vessel Type (1996)

Vessel Type	% of World Commercial Ship Fleet	% of World Commercial Fleet Tonnage	Percent of World Ship N Emissions
Bulk Cargo	15	67	33
General Cargo	23	18	31
Passenger, Other	5	1	6
Fishing	23	1	7
Service Craft	15	1	10
Military	19	11	13

Source: Corbett and Fischbeck, 1997

[1] J. S. Carlton, et al., *Marine Exhaust Emissions research Program*. Lloyds Register Engineering Services, London, 1995; *Marine Exhaust Emissions Research Programme: Steady State Operation including Slow Speed Addendum*. Lloyds Register of Shipping, London, 1990.

[2] J. J. Corbett and P. Fischbeck, "Emissions from Ships." *Science,* Volume 278, pages. 823-825 (1997).

10 While the contribution of marine diesel engines to world-wide NOx levels has been estimated at 4 to 14 percent, it is important to note that a disproportionate share of these emissions may occur along coastlines and in commercial ports, many of which are located in highly populated, industrial settings and many of which are already experiencing serious air pollution. Corbett estimates that approximately 70 percent of these emissions occur within 400 kilometers from shore. Depending on prevailing traffic and wind patterns, and other variables, these emissions can have an important effect on land-side ozone levels.

11 Because the Annex VI NOx limits are so close to average uncontrolled emission levels, the contribution of these engines to NOx inventories is not expected to be greatly reduced. For example, using available domestic data, US EPA estimated the expected reductions from the Regulation 13 emission limits for the U.S. domestic marine diesel NOx inventory, assuming the Regulation 13 standards are implemented as planned beginning 1 January 2000.[3] These results, set out in Table 2, indicate that the Regulation 13 emission limits are expected to result in only a 6 percent reduction in marine diesel NOx emissions in the United States by 2020, and increasing to 7 percent by 2030. Again, while these estimates are only for the United States, they suggest the modest NOx reductions that can be expected world-wide from the current standards.

Table 2
Estimated NOx Reductions from Regulation 13 NOx Emission Limits
United States Domestic Marine Diesel Engine Inventory Only
Engines Above 130 kW (thousands short tons per year)

	2000	2010	2020	2030
Baseline NOx emissions	1005	1117	1244	1390
Controlled NOx emissions	1001	1074	1167	1292
Tons Reduced	4	43	77	98
Percent Reduction	0%	4%	6%	7%

When only propulsion systems on very large ocean-going vessels are considered, the Regulation 13 emission limits are expected to achieve a somewhat higher reduction in marine diesel NOx emissions. For example, US EPA estimated the marine diesel NOx reductions from large marine diesel engines (those above 30 l/cyl displacement) at 13.5 percent in 2020 (see Table 3). These estimates are based on the assumption that the Regulation 13 emission limits are phased in as planned, beginning 1 January 2000.

[3]Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines. United States Environmental Protection Agency, Office of Air and Radiation, Office of Mobile Sources, Engine Programs and Compliance Division, November 1999.

Table 3
Estimated NOx Reductions from Regulation 13 NOx Emission Limits
United States Domestic Marine Diesel Engine Inventory Only
Very Large Marine Diesel Engines Above 130 kW (thousand short tons per year)

	2000	2010	2020	2030	2040
Baseline	273	301	333	368	406
Reduction	1.9	22.5	45	59.2	68.1
Percent Reduction	0.7%	7.5%	13.5%	16.1%	16.8%

Emission control technologies make tighter standards possible

12 Since the time the Regulation 13 NOx emission limits were chosen, the marine industry has continued researching emission control technologies for marine diesel engines. Engine manufacturers are exploring ways to transfer land-based diesel engine technologies to marine diesel engines and are developing new marine-specific technologies. These include combustion optimization (timing retard, combustion chamber geometry, and swirl), advanced fuel injection controls, improved charge air characteristics (jacket-water aftercooling, raw water aftercooling, separate-circuit aftercooling), electronic controls, exhaust gas recirculation (EGR cooling, soot removal), exhaust aftertreatment devices (oxidation catalysts, particulate traps, selective catalytic reduction), and water emulsification.[4] Test data acquired by US EPA in connection with the domestic marine diesel engine control program suggest that the use of these technologies results in significant reductions in NOx emissions. Wartsila NSD has also been experimenting with technologies for very large ocean-going propulsion engines. They estimate that direct water injection technologies can achieve a 50 to 60 percent reduction in NOx emissions. This technology can be used with all fuel types and is available for retrofit operations. Selective Catalyst Reduction (SCR) techniques can achieve 85 to 95 percent reductions in NOx. In addition, Sweden has achieved NOx emissions reductions in excess of 90% for numerous vessels that have applied different technologies as a result of its national program implemented in January 1998.

13 US EPA estimates that a conservative application of these technologies can result in meaningful emission reductions from new marine diesel engines. For example, the US EPA Tier 2 limits are equivalent to a 20 to 25 percent reduction from the Regulation 13 levels, and phase in over 3 years, beginning in 2007. These limits are projected to achieve an additional 7 percent reduction in NOx emissions as early as 2010, increasing to 15 percent in 2020. While the United States domestic commercial marine diesel engine rule did not consider alternative standards for very large engines, it is clear that meaningful emission reductions could be achieved if new low NOx engine technologies were applied to those engines as well.

14 In summary, the above information suggests that it is appropriate for the Committee to begin considering a second tier of emission limits for marine diesel engines at or above 130 kW. A second tier of standards, set at 25 to 30 percent below the Regulation 13 limits, will ensure meaningful NOx reductions and associated reductions in ozone formation. Alternatively, a second tier of standards that flattens the current NOx curve and lowers the overall limits can be considered. These tier 2 standards can be developed to go into effect in 2007, allowing a 7-year period of stability for the current Regulation 13 limits and permitting engine manufacturers to adjust their engine designs to include these new emission control technologies. This second tier

[4]Final Regulatory Impact Analysis, infra.

of standards could also include market incentives to encourage manufacturers to produce even cleaner engines.

15 The Committee is also encouraged to consider including limits for hydrocarbons (HC) and diesel particulate matter (PM). In addition to being a contributor to ozone formation, hydrocarbons include a number of hazardous air pollutants that are known or probable human carcinogens. Because HC emissions may actually increase as NOx limits are tightened, as engine manufacturers recalibrate emissions by focusing only on NOx, the Committee should at least consider capping HC emissions to avoid emissions backsliding. There is a similar trade-off effect between NOx and PM controls. This is of special concern both because diesel engines have high PM levels and because of a growing body of research that associates diesel PM with serious respiratory problems. Several agencies and governing bodies have also designated diesel exhaust or diesel PM as a 'potential' or 'probable' human carcinogen.[5] Thus, the concern for diesel exhaust influences on human cancer hazard is widespread.

Action requested of the Committee

16 The Committee is invited to consider the above views, and begin a dialogue to establish a second tier of emission limits for marine diesel engines. The Committee is further invited to ask the drafting group (DG1) on air pollution to consider what changes to the NOx Technical Code would be necessary to establish a second tier of emission limits and to report its views to the Committee.

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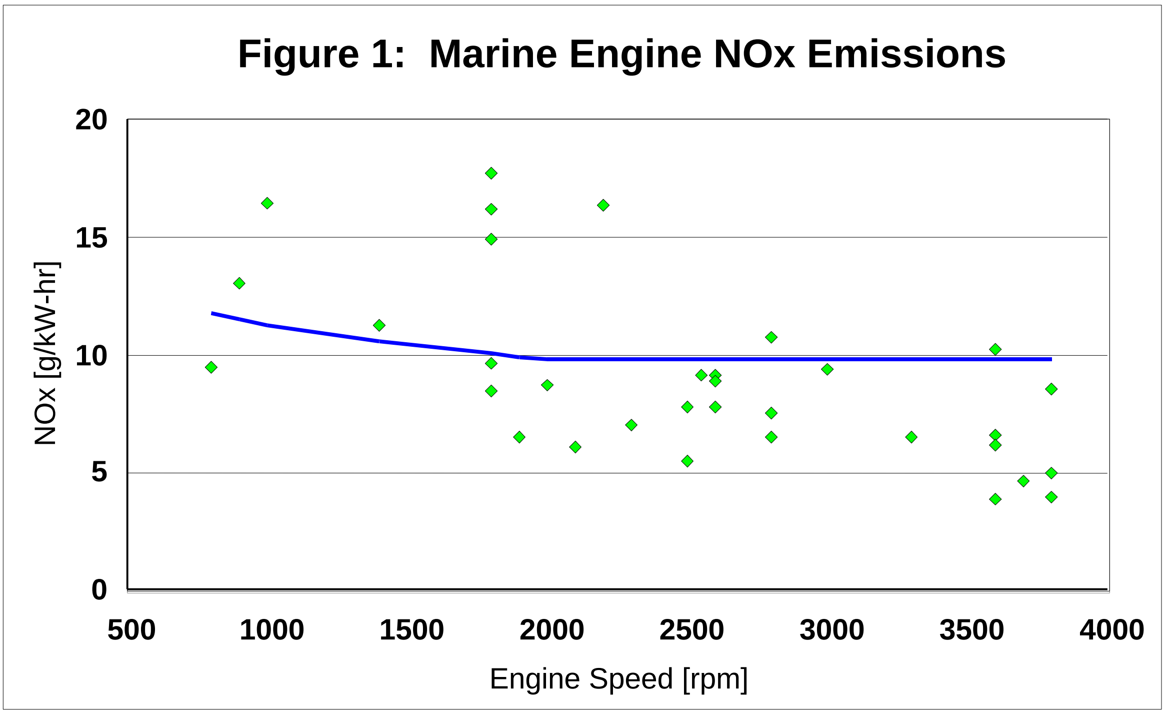
[5] National Institute for Occupational Safety and Health (1988) Carcinogenic effects of exposure to diesel exhaust. NIOSH Current Intelligence Bulletin 50. DHHS (NIOSH) Publication No. 88-116. Centers for Disease Control, Atlanta, GA. National Institute for Occupational Safety and Health (1988) Carcinogenic effects of exposure to diesel exhaust. NIOSH Current Intelligence Bulletin 50. DHHS (NIOSH) Publication No. 88-116. Centers for Disease Control, Atlanta, GA; International Agency for Research on Cancer (1989) Diesel and gasoline engine exhausts and some nitroarenes, Vol. 46. Monographs on the evaluation of carcinogenic risks to humans. World Heath Organization, International Agency for Research on Cancer, Lyon, France; World Health Organization (1996) Diesel fuel and exhaust emissions: International program on chemical safety. World Health Organization, Geneva, Switzerland; Office of Environmental Health Hazard Assessment (1998) Health risk assessment for diesel exhaust, February 1998. California Environmental Protection Agency, Sacramento, CA; National Toxics Program (1998) Report on carcinogens: Background document for diesel exhaust particulates. U.S. Department of Health and Human services, Research Triangle Park, NC.

ANNEX

Figure 1: Marine Engine Nox Emissions



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