International Maritime Organization and Environmental Protection Agency Marine Emissions Regulations

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The IMO MARPOL 73/78 convention and the EPA marine regulations are a complicated set of requirements for engine manufacturers, packagers, builders, operators, and enforcement agencies. In this article I will attempt to highlight the more unfamiliar aspects of the regulations.

IMO Prevention of Pollution From Ships (MARPOL 73/78) 2000—Current

The International Convention for the Prevention of Pollution from Ships, commonly identified as MARPOL, was adapted in 1973 and modified in 1978 and 1997. The convention consists of six annexes dedicated to various aspects of environmental pollution.

- Annex I – prevention of pollution by oil
- Annex II – control of pollution by noxious liquid substances in bulk
- Annex III – prevention of pollution by harmful substances in packaged form
- Annex IV – prevention of pollution by sewage from ships
- Annex V – prevention of pollution by garbage from ships
- Annex VI – prevention of air pollution from ships

Before an annex can be put into force, it must be ratified by an agreed-upon number of countries representing an agreed-upon amount of worldwide shipping tonnage. The latest annex to be adopted was Annex VI in May 2004. This annex was put into force one year later (May 2005) and provided a three-year period for ships to obtain the necessary documents to certify that each vessel met the requirements.

As of September 2008, 52 countries—representing 80.4 percent of the world's shipping tonnage—have ratified Annex VI.[1] In October 2008, the United States ratified MARPOL Annex VI. The enter-into-force date is three months after the U.S. submits the documents to the IMO Secretary-General. The annex establishes:

- limits of exhaust emissions for sulfur oxide (SOx);
- prohibition of deliberate emission of ozone-depleting substances;
- prohibition of on-board incineration of certain products;
- limits for exhaust emissions for nitrogen oxides (NOx).

All the sections of Annex VI are important toward improving air quality, and the maritime industry needs to understand and follow the requirements.

NOx Requirements for Engine Manufacturers

The MARPOL Protocol 97 Annex VI was not ratified until May 2004 and did not go into effect until May 2005. However, the requirements outlined in the NOx technical code are retroactive back to January 1, 2000. Therefore, engine manufacturers started producing engines with power levels equal to or greater than 130 kW (175 hp) that previously met the requirements in January 2000. The NOx limits range from 9.8 to 17.0 g/kW-hr, depending on rated engine speed. The limits are based on specific test cycles defined by ISO 8178-4. These test cycles represent typical load cycles in various applications, and the installed engines need to meet the NOx limits for their particular applications. The test cycles are:

- C1 – variable-speed, variable-load applications (auxiliary applications);
- D2 – constant-speed, variable-load applications (auxiliary applications);
- E2 – constant-speed, variable-load marine applications (controllable pitch props);
- E3 – heavy-duty marine engines (propeller law);
- E5 – craft < 24 m (79 ft) in length (propeller law).

Engine manufacturers are required to submit the test data to a recognized agency to certify that an engine meets these requirements. In some cases, this requires the certifying agency to witness the engine test and emissions measurement. Depending on the ratifying country, the recognized agency may be different.

In the U.S., the recognized agency is the Environmental Protection Agency (EPA). In many other countries, it is a marine classification society such as ABS, DNV, Lloyd's Register, BV, etc. The NOx code allows engine manufacturers to certify a "family" of engines or ratings that meet the air emissions requirements. However, the statement of voluntary compliance or the engine international air pollution prevention certificate and technical file must be specific as to the engine serial number, and related to the appropriate test cycle that the engine is being used in.

The NOx code does not require engine manufacturers to provide an engine label stating that the engine meets these requirements, but some engine manufacturers have elected to label the engine. However, this is not sufficient to identify the engines as meeting the requirements. Only a statement of voluntary compliance or engine international air pollution prevention certificate with the technical file is sufficient to demonstrate engine compliance.

NOx Requirements for Vessel Owners

The vessel owner is responsible for ensuring that installed diesel engines meet the requirements of MARPOL Protocol 97 Annex VI with regard to NOx output and appropriate test cycle.

The technical code requires that the following types of engines meet the NOx output levels:

- installed on vessels with keels laid on or after January 1, 2000, 400 gross tons or more, engaged in international travels, or flagged by one of the ratifying countries;
- installed on vessels with keels laid on or after January 1, 2000, less than 400 gross tons, and the ratifying country has established it as the governing regulation for that country or particular application (i.e. a fishing vessel);
- operating on floating drill rigs and other platforms unless they are solely dedicated to the exploration, exploitation, and associated offshore processing of seabed mineral resources;
- subjected to a major modification, independent of the year the keel was laid. Major modifications are identified as:
    - new engine installed that was built after January 1, 2000;
    - power greater than 10 percent of the engine being replaced, rebuilt, or remanufactured;
    - "substantially modified" (fuel injection timing, fuel injection equipment, charge air system, combustion system).

Vessel owners need to request an inspection from a recognized agency to issue a vessel international air pollution prevention (IAPP) certificate. In the U.S., the agency is the Coast Guard, while other countries may use marine societies or other governmental agencies. In order for one of these agencies to issue the IAPP for the vessel, the owner must have a statement of voluntary compliance or engine international air pollution prevention certificate and a technical file aboard the vessel for each engine above 130 kW (175 hp).

Owners of U.S.-flagged vessels engaged in international travels need to be aware that other countries might not recognize EPA documents. Therefore, owners may need to obtain from the engine manufacturer a set of documents issued by an agency other than the

EPA. Because independent agencies charge engine manufacturers to issue these documents, the engine manufacturers may, in turn, charge the owner, builder, or equipment manufacturer. The owner is also responsible for maintaining the engine service log of emissions-related components identified in the technical file, and must be prepared to present it during any vessel inspection.

Tier I Standards and Timing			
Displacement (L/cyl)	Date Commercial and Recreational	Maximum Test Speed (RPM)	NOx (g/kW-hr)
≥ 2.5	2004	< 130	17.0
		130 ≤ N < 2000	$45*N^{-0.2}$
		≥ 2000	9.8

Tier II Standards and Timing						
Category	Displacement (L/cyl)	Commercial Date	Recreational Date	NOx + HC (g/kW-hr)	CO (g/kW-hr)	PM (g/kW-hr)
1	D < 0.9 (P ≥ 37 kW)	2005	2007	7.5	5.0	0.40
	0.9 ≤ D < 1.2	2004	2006	7.2	5.0	0.30
	1.2 ≤ D < 2.5	2004	2006	7.2	5.0	0.20
	2.5 ≤ D < 5.0	2007	2009	7.2	5.0	0.20
2	5.0 ≤ D < 15.0	2007	N/A	7.8	5.0	0.27
	15.0 ≤ D < 20.0 (P < 3300 kW)	2007	N/A	8.7	5.0	0.50
	15.0 ≤ D < 20.0 (P ≥ 3300 kW)	2007	N/A	9.8	5.0	0.50
	20.0 ≤ D < 25.0	2007	N/A	9.8	5.0	0.50
	25.0 < D < 30.0	2007	N/A	11.0	5.0	0.50

Enforcement and Penalties

Only countries that have ratified MARPOL Annex VI can enforce the regulation. This applies to vessels flagged by the ratifying country and vessels flagged by other countries but operating in the ratifying countries' territorial waters. Penalties for regulation violations are established by the ratifying countries and can be as severe as vessel detention.

EPA Requirements

The EPA began regulating emissions of diesel engines greater than 0.9 L/cyl and 37 kW used on U.S.-flagged vessels in January 2004.[2] The EPA took a tiered approach to the emission reductions, with each tier consisting of a "phasing in" of engine displacement, power density, and power ranges.

The marine industry includes a diverse mix of applications, and the EPA put marine engines into different categories and based its regulations accordingly:

- category 1 engines: displacement range of 0.9 L/cylinder to 5.0 L/cylinder;
- category 2 engines: displacement range of 5.0 L/cylinder to 30 L/cylinder;
- category 3 engines (not regulated by this rule): displacement of greater than 30 L/cylinder.

An engine's category will determine when it must become compliant with the appropriate tier requirements. Additionally, the type of vessel the engine will be used in also determines when the rule becomes effective. It is extremely important that all marine industry personnel understand how the EPA defines recreational and commercial vessels because this determines if a recreational or commercial engine can be used in the vessel.[3]

As the table indicates, all the engines need to meet the Tier II requirements today.

Requirements for Manufacturers, Dressers, Owners

Engine manufacturers are subjected to various testing, document controls, and labeling requirements. Once an engine is tested to the appropriate test cycle (same as defined in IMO MARPOL Protocol 97 Annex VI) and EPA approves the data submitted for certification, the engines can be produced. The engine manufacturer must permanently label the engine for the intended use.

For example, if engines are going into a yacht that meets the EPA definition of a recreational vessel, then the engines must have a label that states that it is for use in a recreational vessel. However, if the vessel is greater that 100 gross tons and a person will pay to be on the vessel (i.e. a charter), then that vessel becomes a commercial vessel and the engines must be labeled as commercial engines. All auxiliary engines are considered commercial engines.

Engine manufacturers cannot produce new engines for introduction into the U.S. commerce stream that do not meet the current emissions levels for the engine displacement per cylinder and power levels.

The marine emissions rules have different emissions levels than land-based engines, such as heavy-duty highway engines (40 CFR part 86), non-road diesel engines (40 CFR part 89), or locomotive engines (40 CFR part 92). However, the marine rule allows a marine

dresser[4] to use these land-based engines in marine applications. This includes packagers for gen-sets or other auxiliary drives, such as a pump engine on a barge or an engine used in a Hovercraft.

The marine dresser must use an engine that meets the current standard under which it was certified and cannot change the engine in any way that will affect emissions. The dresser must use an engine certified to the appropriate test cycle for the application. For example, if a gen-set is packaged with a land-based engine to be installed on the deck of the barge, it must be certified to the D2 test cycle.

Another example of the barge application is the pump drive engine to pump the cargo off. Historically, this application has been a land-based engine that is a variable-speed engine, allowing the operators to set the RPM at the optimum speed to pump the cargo. Because different speeds are used and engine loading is dependent on the type of cargo, this would be a variable-speed, variable-load application requiring an engine certified to C1 test cycle. In addition to the above, the marine dresser must also add a permanent label (per section 94.907 of 40 CFR part 94) and report to the EPA the number of engines dressed annually.[5]

Manufacturers of new vessels or organizations that make major modifications to vessels are responsible for selecting the proper engine for their applications. According to the EPA, a new vessel is defined as:

- a vessel for which the purchaser has not received the equitable or legal title;
- a vessel that has been modified such that the value of the modifications exceeds 50 percent of the value of the modified vessel;
- an imported vessel that has already been placed into service but has engines manufactured after the date specified in this regulation.

In the case of the major modification, if the above criteria is met but the engines were not changed during the modification, engines that meet the current tier level at the date the modification was completed would have to be fitted.

The engines must be installed in a manner that meets the engine manufacturer's installation guidelines. The cooling system, exhaust system, and air inlet systems are critical to the installation. The guidelines established by the engine manufacturers are there to ensure the engines operate within the combustion system tolerance to ensure the exhaust emissions are within limits.

Owners of vessels are prohibited from tampering with the engine or the emissions controls. Owners are also responsible for ensuring that engines are rebuilt or replaced with engines such that they will meet the same emissions levels as the original engines. These regulations should be carefully reviewed when investigating used or reconditioned engines. Records on the replacement or rebuilt engines must be understandable and available to the enforcing agencies for two years after the work has been completed.

Enforcement and Penalties

The EPA Office of Enforcement and the USCG are authorized to enforce the requirements of this regulation. The rules have been established in an attempt to simplify the inspection of engines meeting these requirements. However, the rules make various allowances to accommodate the diversity of the marine industry.

This makes the task of inspection and confirmation difficult. Engine manufacturers, vessel manufacturers, retrofit organizations, and owners are all subject to fines and other penalties if violations are identified.

Recent Action

In May 2008, the EPA released the final rule for a new set of standards for exhaust emissions from marine diesel engines. Again, it has taken a tiered approach to emissions reductions, and each tier will consist of a "phasing in" of engine displacement and power ranges. In the new rule, the EPA has modified the category of engines.

- category 1 engines: displacement range of 0.9 L/cylinder to 7 L/cylinder
- category 2 engines: displacement range of 7 L/cylinder to 30 L/cylinder
- category 3 engines (the EPA has proposed a separate rule for engines of this size): displacement of greater than 30 L/cylinder

It's also important to understand which emissions would be regulated. Between 2009 and 2018, the proposed Tier III standard will reduce NOx plus hydrocarbon (HC) output by 20 percent and particulate matter (PM) by 50 percent from current Tier II levels. Between 2014 and 2017, the proposed Tier IV standard will reduce NOx output by 80 percent and PM output by 90 percent from current Tier II levels.

An engine's category will determine when it has to become compliant with the appropriate tier requirements. However, the EPA breaks it down further within each category and spells out which horsepower ranges have to meet which emissions standards in each model year.

Category 1 Tier III Standards and Timing

Power Density and Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx + HC (g/kW-hr)
all	disp < 0.9	kW (hp) < 19 (25)	2009	0.4	7.5
		19 ≤ kW < 75	2009	0.30	7.5
		25 ≤ hp < 100	2014	0.30	4.7
Commercial engines with kW/L ≤ 35 (hp/L ≤ 47)	disp < 0.9	kW (hp) ≥ 75 (100)	2012	0.14	5.4
	0.9 ≤ disp < 1.2	all	2013	0.12	5.4
	1.2 ≤ disp < 2.5	kW (hp) < 600 (805)	2014	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2014	0.11	5.6
	2.5 ≤ disp < 3.5	kW (hp) < 600 (805)	2013	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2013	0.11	5.6
	3.5 ≤ disp < 7.0	kW (hp) < 600 (805)	2012	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2012	0.11	5.6
Commercial engines with kW/L > 35 (hp/L > 47) and all recreational engines	disp < 0.9	75 to <3700 kW 100 to <4962 hp	2012	0.15	5.8
	0.9 ≤ disp < 1.2		2013	0.14	5.8
	1.2 ≤ disp < 2.5		2014	0.12	5.8
	2.5 ≤ disp < 3.5		2013	0.12	5.8
	3.5 ≤ disp < 7.0		2012	0.11	5.8

Category 2 Tier III Standards and Timing

Power Density and Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx + HC (g/kW-hr)
Commercial engines	7.0 ≤ disp < 15.0	kW (hp) ≤ 3700 (4962)	2013	0.14	6.2
	15.0 ≤ disp < 20.0	kW (hp) ≤ 3300 (4425)	2014	0.34	7.0
		3300 < kW ≤ 3700 4425 < hp ≤ 4962	2014	0.27	7.0
	20.0 ≤ disp < 25.0	kW (hp) ≤ 3700 (4962)	2014	0.27	9.8
	25.0 ≤ disp < 30.0	kW (hp) ≤ 3700 (4962)	2014	0.27	11.0

New Vessels and Repowers

The new rule will regulate any engine installed on a new vessel flagged or registered in the U.S. and applies to replacement engines and rebuilt engines.

The regulation defines a "new vessel" as:

- a vessel for which the purchaser has not received the equitable or legal title;
- a vessel that contains no category 3 engines and has been modified such that the value of the modifications exceeds 50 percent of the value of the modified vessel. The notice of proposed rulemaking provides the following equation to determine if the fractional value of the modification exceeds 50 percent:

  % of value = [(assessed value after modification)-(assessed value before modification)] / 100% (assessed value after modification).
- a vessel with category 3 engines that has undergone a modification that substantially alters the dimensions or carrying capacity of the vessel, changes the type of vessel, or substantially prolongs the vessel's life;
- an imported vessel that has already been placed into service but has engines manufactured after the date specified in this regulation.

Engines used for replacement, either as a repower or as a result of an engine failure, must meet the emissions levels in effect at the date of the replacement.

For example, let's imagine one of the engines fails in a twin-engine vessel and cannot be repaired. The owner is required to replace it with the current tier engine. It is possible to use an engine equal to the failed engine if it can be shown that no other engine on the market is available and that the vessel will not function properly with the higher-tier engine. The EPA must approve this substitution. There are a number of engine labeling requirements, and the engine manufacturer must take possession of the failed engine.

The new rule also includes a requirement for remanufactured engines. This requirement applies to commercial marine engines of more than 600 kW (805 hp) built between 1973 and when Tier II went into effect. The EPA is defining a remanufactured engine as an engine that has all cylinder liners replaced in a single maintenance event or over a five-year period. For this rule, "replaced" also includes removing, inspecting, and requalifying a liner. The rule requires an owner/operator who is remanufacturing the engine to use a certified system if one is available. The EPA will maintain a list of certified systems on its website. If no system is available for the engine, it is not required.

Engine Installation Requirements

Engine manufacturers are required to provide emissions-specific installation requirements. Installers that fail to follow these instructions may be subject to fines and other penalties.

Category 1 and 2 Tier IV Standards and Timing						
Power Density and Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx (g/kW-hr)	HC (g/kW-hr)
Commercial only	all	600 ≤ kW < 1400 805 ≤ hp < 1877	2017	0.04	1.8	0.19
	all	1400 ≤ kW < 2000 1877 ≤ hp < 2682	2016	0.04	1.8	0.19
	all	2000 ≤ kW < 3700 2682 ≤ hp < 4962	2016	0.04	1.8	0.19
	disp. < 15.0	kW (hp) ≥ 3700 (4962)	2014	0.12	1.8	0.19
	15.0 ≤ disp < 30.0		2014	0.25	1.8	0.19
	all		2016	0.06	1.8	0.19

Engine manufacturers must label the engine with information about the emissions certification. If the engine is installed in a way that makes this label hard to read during normal maintenance, owners must request a duplicate label and place it in a visible location on the vessel.

Tier III Issues

It appears that a Tier III marine engine will not be much different than a Tier II marine engine. The Engine Manufacturers Association (EMA), whose members have worked with the EPA during the development of this rule, believes the Tier III emissions levels can be achieved through in-cylinder technologies. An engine at a given power level certified as a Tier II engine might have a larger displacement for the same power to meet Tier III levels. The EMA also believes that a Tier III engine will not require ultra-low sulfur diesel (ULSD) fuel.

Those who have to replace a non-certified Tier I or Tier II engine after Tier III becomes effective will face the biggest challenge. It may become more difficult to find an engine that will physically match the older engine at the same power level. This could be critical for multi-engine vessels.

Tier IV Issues

EMA members agreed that Tier IV will require after-treatment devices, which will require ULSD fuel. The regulations state that the engine and the vessel will be labeled as such. It will be considered a violation if ULSD fuel is not used, and owners may be subject to fines and other penalties.

If a vessel has an engine installed that uses a selective catalytic reduction system with urea[6] or other reductants, the owner or operator must report to the EPA within 30 days of any operation of the engine without the appropriate urea. Failure to do so may result in fines and other penalties.

The after-treatment devices are substantial in size. Tier IV requirements are only for commercial vessels and engines with power ratings greater than 600 kW (805 hp). The after-treatment devices will be required to reduce NOx and particulate matter. For NOx reduction, an SCR system using urea injection seems to be the best alternative at this time. For particulate matter reduction, an active diesel particular filter, combined with a diesel oxidation catalyst, seems to be the best alternative.

The new rule has identified that Tier IV engines are not required as a replacement engine. This is due to the potential for extensive vessel modification to fit the after treatment devices and the effect it could have on vessel performance and safety.

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Endnotes:

1. International Maritime Organization, "Status of Conventions by Country," May 2008.
2. The regulation is detailed in Federal Register 40 CFR.
3. Per 40 CFR Part 94.2, a recreational vessel "has the meaning given in 46 U.S.C. 2101 (25), but excludes 'passenger vessels' and 'small passenger vessels' as defined by 46 U.S.C. 2101 (22) and (35) and excludes vessels used solely for competition. In general, for this part, 'recreational vessel' means a vessel that is intended by the vessel manufacturer to be operated primarily for pleasure or leased, rented, or chartered to another for the latter's pleasure, excluding the following vessels:
   (1) Vessels of less than 100 gross tons that carry more than 6 passengers (as defined in this section).
   (2) Vessels of 100 gross tons or more that carry one or more passengers (as defined in this section).
   (3) Vessels used solely for competition."

   A commercial vessel is defined as "a vessel that is not a recreational vessel."
4. A dresser is any entity that modifies a land-based engine for use in a marine application.
5. The reader is advised to consult 40 CFR part 94 and the technical amendments associated with it for specific details on how to properly apply this marine dresser provision properly.
6. Urea is essentially a liquid, non-hazardous form of ammonia that is injected into the exhaust gas stream as part of the selective catalytic reduction process for reduction of NOx emissions.