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Foghorn Focus:

Environmental Issues

Turning Black Water Green?

EPA Marine Emissions for 2009-2018

Hybrid Propulsion

EPA Marine Emissions for 2009-2018

By Carl J. Micu, product manager, sales support for John Deere Power Systems

The U.S. Environmental Protection Agency (EPA) has proposed a new set of standards for exhaust emissions from marine diesel engines. At first glance, these regulations can seem confusing, but with a little help, you can understand what these rules would mean for you and your marine application.

First, it helps to understand the timeline the EPA is using to implement these regulations. The EPA has taken a tiered approach to emissions reductions, and each tier will consist of a "phasing in" of engine displacement and power ranges.

Because the marine industry includes such a diverse mix of applications, the EPA puts marine engines into different categories and bases its regulations accordingly. Category 1 engines are the smallest, with a displacement range of 0.9 L/cylinder to 7 L/cylinder. Category 2 engines are mid-sized, with a displacement range of 7 L/cylinder to 30 L/cylinder. Category 3 engines are the largest, with displacement of greater than 30 L/cylinder and are not regulated by this rule.

It's also important to understand which emissions would be regulated. Between 2009 and 2018, the proposed Tier 3 standard will reduce nitrogen oxide (NOx) plus hydrocarbon (HC) output by 20 percent and particulate matter (PM) by 50 percent from current Tier 2 levels. Between 2014 and 2017, the proposed Tier 4 standard will reduce NOx output by 80 percent and PM output by 90 percent from current Tier 2 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 what emissions standards in each model year. The details for each engine category are found in the following charts.

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 as well.

First, let's make sure we know what "new vessel" means in terms of the regulation:

- Vessel for which the purchaser has not received the equitable or legal title
- 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 (NPRM) 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)
- 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
- 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, if you are running a twin-engine vessel and one of the engines fails and it cannot be repaired, you are 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.

When an engine rebuild is required, you must rebuild it with components equivalent to the original components in order to keep the emissions output at the original levels. If aftertreatment is used, you must service the aftertreatment devices at the same time.

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.

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

Tier 3 Standards and Timing for Category 1 Engines

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 25 ≤ hp < 100	2009	0.30	7.5
			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	kW (hp) ≥ 75 (100)	2012	0.15	5.8
	0.9 ≤ disp < 1.2	kW (hp) ≥ 75 (100)	2013	0.14	5.8
	1.2 ≤ disp < 2.5	kW (hp) ≥ 75 (100)	2014	0.12	5.8
	2.5 ≤ disp < 3.5	kW (hp) ≥ 75 (100)	2013	0.12	5.8
	3.5 ≤ disp < 7.0	kW (hp) ≥ 75 (100)	2012	0.12	5.4

Tier 3 Standards and Timing for Category 2 Engines

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
		kW (hp) ≤ 3300 (4425)	2014	0.34	7.0
	15.0 ≤ disp < 20.0	3300 < kW ≤ 3700 4425 < hp ≤ 4962	2014	0.27	8.7
	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

Tier 4 Standards and Timing for Category 1 and 2 Engines

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
Commercial only	all	1400 ≤ kW < 2000 1877 ≤ hp < 2682	2016	0.04	1.8	0.19
Commercial and recreational	all	2000 ≤ kW < 3700 2682 ≤ hp < 4962	2016	0.04	1.8	0.19
Commercial and recreational	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

normal maintenance, you must request a duplicate label and place it in a visible location on the vessel.

Tier 3 Issues

It appears that a Tier 3 marine engine will not be much different than a Tier 2 marine engine. The Engine Manufacturers Association (EMA), whose members have worked with the EPA during the development of this proposal, believes the Tier 3 emissions levels can be achieved through in-cylinder technologies. An engine at a given power level certified as a Tier 2 engine might have a larger displacement for the same power to meet Tier 3 levels. Bigger displacement usually means more weight and more fuel consumption. The EMA also believes that a Tier 3 engine will not require ultra-low sulfur diesel (ULSD) fuel.

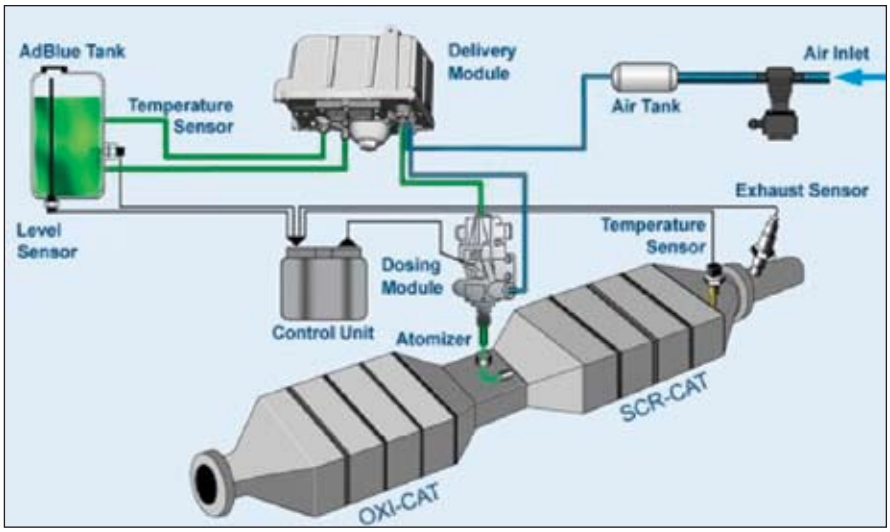
Those who have to replace a non-certified, Tier 1 or Tier 2 engine after Tier 3 becomes effective will face the biggest challenge. It may become more difficult to find an engine that will physically match the older engine at the same power level. This could be critical for multi-engine vessels.

Tier 4 Issues

EMA members agreed that Tier 4 will require aftertreatment devices, which will require ULSD fuel. The regulations state that the engine and the vessel be labeled as such. It will be considered a violation if ULSD fuel is not used, and you may be subject to fines and other penalties.

If a vessel has an engine installed that uses a selective catalytic reduction (SCR) system with urea 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 aftertreatment devices are substantial in size. The EPA is attempting to identify vessels that



Typical SCR System.

can accommodate these devices by applying the Tier 4 requirement only to commercial vessels and engines greater than 600 kW (805 hp). The aftertreatment devices will be required to reduce NOx and PM. For NOx reduction, an SCR system using urea injection seems to be the best alternative at this time. For PM reduction, an active diesel particular filter (DPF) combined with a diesel oxidation catalyst (DOC) seems to be the best alternative.

Simple SCR Description

Selective catalytic reduction works much like a catalytic converter on a car. Exhaust gas containing the NOx emissions from the combustion process is mixed with urea. The mixed gases travel through a series of catalytic layers, which cause the NOx to react with the ammonia from the urea. The reaction converts the NOx to pure nitrogen and water.

The system is made up of urea holding tanks, a urea dosage pump and controller, a urea injection lance, a NOx measurement and control system, and a catalyst stack.

Various concerns associated with a urea SCR include:

- Availability of urea where the vessels are fueled
- Storage issues associated with urea freezing (will freeze at 12° F)
- Vessel duty cycles (exhaust temperatures have to be high enough to allow the reactions to occur)
- How to ensure urea is being used
- Water-cooled exhaust systems
- SCR onboard space requirements
- Weight impact

So, just how large and heavy are these devices, and do they affect vessel performance? The EPA estimates that the volume for the catalyst part of the SCR system will be 2.5 times the engine displacement. Marty Robbins, general manager of Baylink and PVA board member, has provided some information about sister ships *M/V's Solano*, *Intintoli* and *Mare Island* to demonstrate the effect of an SCR system.

All three ships are passenger-only, high-speed aluminum catamarans, and they are all 135 feet long and support 300 passengers. The *M/V Intintoli* and *Mare Island* are powered by MTU16V-396TE74L engines rated at 2680 hp at 1900 RPM. The *M/V Solano* is powered by 16V-4000M70 engines rated at 3110 hp at 2000 RPM. The *Solano* is the only ship that has an SCR system, which is a Steuler Anlagenbau GmbH & Co model that provides 50 percent NOx reduction. The SCR system adds 8,206 lbs to the vessel's weight and cost $450,000, with an additional $50,000 for SCR infrastructure. All three vessels reach 34 knots, but the *Solano* requires the extra power and consumes 100 gallons more diesel fuel per round trip compared to the other two vessels. It also consumes 100 gallons of urea per day. The cost of urea is in the range of $1.50/gallon and, depending on how capital cost for the on-highway infrastructure is applied, could be considerably higher. In addition, the *Solano* exhibits a number of performance issues, including noticeable stern trim, a larger wake and slower acceleration.

Simple DOC/DPF Description

A diesel oxidation catalyst uses a chemical reaction to break down pollutants in the exhaust gas. It typically removes some percentage of PM and also will remove HC and carbon monoxide (CO).

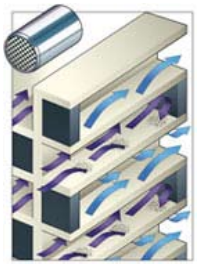
A diesel particulate filter removes PM from diesel exhaust by physical filtration. The most common type is a ceramic (cordierite or silicon carbide) honeycomb monolith. The structure is like an emissions catalyst substrate but with the channels blocked at alternate ends. The exhaust gases must therefore flow through the walls between the channels, and the particulate matter is deposited on the walls.

Just how large and heavy are these devices?

DPFs are similar to a silencer from a packaging standpoint but of course weigh more. The EPA estimates that a DOC/DPF volume will be 1.7 times the engine displacement. What does this mean? Let's look at an example.

As the name indicates, a DPF

will filter or trap the PM from the exhaust. To prevent plugging, the PM must be removed from the filter. This is accomplished by regeneration or burning off the soot, either passively or actively. Passive regeneration is possible when there is sufficient temperature in the exhaust system; active regeneration requires the addition of diesel fuel to the exhaust to generate the roughly 1,200 F-degree temperatures needed to burn off the soot. Due to the wide variety of applications in the marine industry, EMA believes active regeneration will be needed.



Typical Wall-Flow Filter.

Various concerns are associated with the use of a DPF:

- ULSD availability
- Temperatures during regeneration
- Serviceability of DPF (needs to be removed for cleaning)
- Water-cooled exhaust systems
- DPF onboard space requirements
- Weight impact
- Temperature for regeneration
- Plugging of DPF

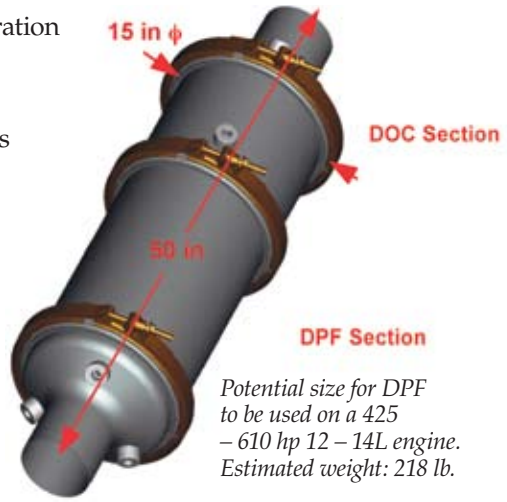
Comments being requested by EPA

The EPA is still weighing certain aspects of the emissions regulations. For example, should the EPA emissions regulations apply to engines installed in foreign vessels entering U.S. ports? (See page 15968 of NPRM for details.)

The EPA is concerned that the Tier 4 part of the regulation will cause vessels to be designed with multiple engines below the 600 kW (805 hp) range (See page 15978 of NPRM for details). The EPA is considering the following:

- Requiring Tier 4 for all vessels with total power greater than 1100 kW (1475 hp)
- Requiring vessel manufacturers to demonstrate to the EPA that they are not attempting to circumvent the Tier 4 requirement
- Basing Tier 4 requirements on vessel size (or other characteristics)

The EPA is a strong supporter of reducing emissions of the current fleet. In the railroad section of this NPRM, the EPA regulates rebuilding these engines with kits that will reduce exhaust emissions. The EPA is seeking comments as it considers whether marine engines of more than 600 kW (805 hp) should have kits available at the time of rebuild to reduce the emissions output (see page 115943 and Section VII .A(2)). In summary, the EPA is considering:



Potential size for DPF to be used on a 425 – 610 hp 12 – 14L engine. Estimated weight: 218 lb.

- Mandatory emissions upgrades at time of rebuild if kits are available beginning in 2008
- Mandatory emissions upgrades to meet specific requirements for "high sales volume engine models" as determined by the EPA beginning in 2013
- Controlling the price of the kits

When reviewing this topic, some items to consider include:

- Are your vessel's current engines still in production?
- What is the cost to rebuild the engine versus buying new?
- Is the fuel consumption of new model engines sufficiently better than the older engines to justify replacement versus rebuild?
- Is 600 kW (805 hp) a reasonable cutoff point, or is a different criteria – more

In order to help you get through the 351-page NPRM document, here is a list of some of the important marine-related sections for your reference:

Section I .A What is EPA Proposing?
Section III.A What Locomotives and Marine Engines are Covered?
Section III.C(2) Marine Standards
Section IV.C(2) Replacement Engines
Section VII.A(2) Standards for Engines on Existing Vessels
Section X
- 1042.1 Applicability
- 1042.15(c) Do any other regulation parts apply to me?
- 1042.110 Recording urea use and other diagnostic functions
- 1042.130 Installation instructions for vessel manufacturers
- 1042.135 Labeling
- 1042.401 In-use Testing
- 1042.601 General Compliance Provisions for marine engines and vessels
- 1042.660 Requirements for vessel manufacturers, owners and operators
- 1042.801 Definitions

The following sections from 40 CFR Part 94 Final Rule should be reviewed
- 1068.101 Prohibited actions and applicable fines
- 1068.120 Requirements for rebuilding an engine
- 1068.240 Exemptions for replacement engines

in line with matching the marine engines to the railroad engines – more appropriate?

Summary

There is a lot of information to review in order to determine how these rules will affect the passenger vessel industry. I hope this summary has helped you understand how you will be affected. The PVA Regulatory Committee met with the EPA in June to obtain additional understanding of this proposal. PVA will submit appropriate comments to the docket, but as always, we encourage individuals to submit their comments also.

The NPRM can be found on the Government Regulations Web site, www.regulations.gov, under docket number EPA-HQ-OAR-2003-0190. The closing date for comments was July 2, 2007, but it would still be useful for vessel operators to send in comments subsequently. ■

Summary of PVA Member Survey

The Regulator Committee has been soliciting vessel members to provide information related to their vessels and the engines used in them. I want to thank all of those who have submitted information. If you did not submit your information, we will be glad to accept it at any time. Following are some of the information that we obtained:

Number of companies that replied	**28**
Total number of vessels	**132**
Number of vessels with single propulsion	8
Number of vessels with twin propulsion	116
Number of vessels with triple propulsion	4
Number of vessels with quad propulsion	4
Vessels with propulsion engines < 805	89
Vessels with propulsion engines > 805	43
Vessels with one gen-set	28
Vessels with two gen-sets	86
Vessels with three gen-sets	8
Vessels without gen-sets	10

Total number of propulsion engines	**266**
Propulsion engines between 25 and 100 hp	3
Propulsion engines < 805 hp	182
Propulsion engines > 805 hp	68
Total number of gen-sets	**224**
Gen-set engines < 25 hp	6
Gen-set engines between 25 and 100 hp	43
Gen-set engines < 805 hp	159
Gen-set engines > 805 hp	12