STATEMENT
OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S
ADVANCED NOTICE OF PROPOSED RULEMAKING FOR THE CONTROL OF EMISSIONS FROM NEW MARINE COMPRESSION-IGNITION ENGINES AT OR ABOVE 30 LITERS PER CYLINDER

Docket ID No. EPA-HQ-OAR-2007-0121

February 22, 2008

MECA is pleased to provide comments in support of EPA's Advanced Notice of Proposed Rulemaking for the Control of Emissions from New Marine Compression-Ignition Engines at or above 30 liters per cylinder. We believe an important opportunity exists to significantly reduce emissions from Category 3 marine diesel engines through the combination of continued improvements in engine designs, the use of lower sulfur fuels, and the application of appropriate exhaust emission controls. MECA agrees with EPA's assessment that the focus of the proposed standards should include a two-phase approach that would first achieve modest particulate matter (PM) and SOx reductions through the use of lower sulfur fuels and/or exhaust gas cleaning technologies (as early as 2011) and then provide meaningful, long-term reductions in NOx emissions through the application of high-efficiency, catalyst-based emission controls (e.g., selective catalytic reduction [SCR] catalysts) to these engines in the 2016 timeframe. Given the growing experience with SCR installations on large ocean-going vessels, MECA believes that Tier 3-type NOx emission standards on these large marine diesel engines could be implemented as early as 2014 and would provide significant NOx emission reductions to ships, especially during operations near coastal areas with significant population centers.

MECA is a non-profit association made up of the world's leading manufacturers of mobile source emission controls. MECA member companies have over 30 years of experience and a proven track record in developing and commercializing exhaust emission control technologies. A number of our members have extensive experience in the development, manufacture, and commercial application of emission control technologies for diesel engines, including diesel engines used in nonroad applications. Our members are partnering with vehicle and engine manufacturers to make "clean diesel" vehicles and equipment a reality here in North America. A recent survey of MECA's members revealed that our industry has invested more than $2 billion in R&D and capital expenditures to develop, optimize, and commercialize advanced emission control technology to substantially reduce emissions from on-road and off-road diesel engines.

Technologies to reduce diesel emissions from marine engines, such as diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), and selective catalytic reduction (SCR) systems, are commercially available today. These catalyst-based emission control technologies have already been installed on millions of new light-duty and heavy-duty vehicles and equipment and as retrofit technology on hundreds of thousands of existing on-road and off-road diesel engines worldwide to provide significant reductions in diesel particulate matter (PM) and oxides of nitrogen (NOx) emissions, as well as reductions in hydrocarbon (including toxic hydrocarbons like poly-aromatic hydrocarbons) and carbon monoxide (CO) emissions. In the case of catalyst-based PM reduction technologies such as catalyst-based DPFs or DOCs, their successful application is dependent on the use of low or ultra-low sulfur diesel fuel since sulfur levels in the fuel can both deteriorate catalyst performance and contribute to PM emissions through the formation of sulfate emissions across the catalyst. This is why EPA's recent final or proposed rulemakings covering new highway, off-road, locomotive, and smaller marine diesel engines include or take advantage of the mandated use of ultra-low sulfur diesel fuel (15 ppm S max.) to facilitate the use of sulfur-sensitive, catalyst-based emission control technologies like DPFs, DOCs, or NOx adsorber catalysts. Similarly, for large ocean-going vessels, the application of catalyst-based DPFs and DOCs for PM reductions would not be practical until fuel sulfur levels are reduced to 500 ppm S, or in some cases even 50 ppm S, or lower. In this ANPRM, EPA has only proposed reducing fuel sulfur levels to a minimum of 1,000 ppm for these large marine diesel engines.

There is growing experience with these "clean diesel" emission control technologies on marine diesel engines. These marine diesel engine applications pose unique operating environments and challenging packaging envelopes for emission control technologies, but proper application engineering has resulted in the successful application of DOCs, DPFs, and SCR catalysts on a variety of marine diesel engines.

Emission Control Technologies for Marine Diesel Engines

MECA would like to provide comments on the experience base with diesel particulate filters, diesel oxidation catalysts, and SCR catalysts on marine diesel engines. Our comments on DPFs and DOCs are specific to marine applications that have low or ultra-low sulfur diesel fuel available. If sulfur levels for ocean-going vessels remain at 1,000 ppm S or higher, engine manufacturers would not be able to take advantage of these catalyst-based technologies for reducing PM levels. Our comments on marine SCR experience provide strong support for the potential of this technology to achieve high efficiency NOx reductions consistent with EPA's proposal for a Tier 3, Category 3 marine diesel engine NOx emission standard. As indicated in EPA's ANPRM, SCR catalyst technology is capable of significant NOx reductions from marine diesel engines even when these engines are operated on fuels with high sulfur levels (e.g., 15,000 to 35,000 ppm S).

Diesel Particulate Filters (DPFs) – Diesel particulate filters are commercially available today, with over 200,000 on-road heavy-duty vehicles worldwide retrofitted with high-efficiency DPFs and over four million new diesel passenger cars in Europe equipped with this technology since 2000. Starting in 2007 here in the U.S. and Canada, essentially all new heavy-duty diesel highway engines have been equipped with diesel particulate filters to achieve EPA's 2007, 0.01 g/bhp-hr PM highway diesel standard. New "clean diesel" light-duty vehicles that are entering the U.S. market will also be equipped with DPFs to achieve compliance with EPA's light-duty Tier 2 PM emission regulations.

To date, the real-world experience with DPFs in these many light-duty and heavy-duty on-road vehicle applications has been very good. Through millions of miles of operation, DPFs continue to provide high reductions in PM emissions in these applications with very few operational problems. Most recently, the launch of catalyst-based filters in the U.S. and Canada on 2007 model year heavy-duty highway engines has received favorable feedback from owners and operators.

These successful on-road DPF applications are generally employing durable ceramic wall-flow filters to achieve in excess of 90 percent reduction in engine-out PM levels over years of operation. Light-duty and heavy-duty new vehicle applications of DPFs rely on combinations of both passive and active regeneration strategies for periodic combustion of soot that accumulates on the filter. In many cases, catalysts displayed directly on the filter substrate and/or located upstream of the filter element have been used to facilitate soot oxidation under normal exhaust temperatures. The use of ultra-low sulfur diesel fuel is an important enabler for the use of catalyst-based PM control technologies such as DPFs and DOCs. Wall-flow ceramic filter elements are now available in a number of material types, including cordierite, silicon carbide, aluminum titanate, and mullite. Substrate manufacturers continue to refine the designs and production processes for these filter elements in order to improve durability characteristics, minimize exhaust backpressure, and make these filter substrates more compatible with catalyst coatings.

More recently, metal substrate filter designs have been developed and introduced for PM control of diesel engines. These designs combine more tortuous flow paths with sintered metal filter elements to achieve intermediate PM filtering efficiencies that can range from 30 to 70 percent depending on engine operating conditions and the soluble content of the diesel particulate matter emitted by the engine. Like ceramic wall-flow filters, these metal filter designs can be catalyzed directly or used with an upstream catalyst to facilitate regeneration of soot captured by the substrate. These metal substrate filter designs have seen application as a retrofit technology on both heavy-duty and light-duty highway diesel engines, have been used by one engine manufacturer (MAN) in Europe for complying with Euro 4 heavy-duty diesel PM limits, and have been introduced by Daimler on their new Smart diesel passenger car in Europe to reduce PM emissions and comply with Euro 4 light-duty emission standards. Due to their more open designs, these metal substrate filter designs can operate over very long timeframes without the need for cleaning the substrate of trapped lubricant oil ash.

Several demonstration projects have been conducted, or are being conducted, in the U.S. to evaluate the feasibility of equipping marine diesel engines with DPFs. In 2006, a U.S. Navy work boat/barge was retrofitted with an active DPF system. Emissions testing results show that the DPF, along with engine modifications, achieved an 85 percent reduction in PM and a 74 percent reduction in NOx emissions relative to the original engine configuration. Active filters employing diesel fuel burners for filter regeneration have been successfully installed in a limited number of marine engine and locomotive applications in Europe. This particular active filter design does not employ catalysts and would therefore be available to diesel engine applications that operate at higher fuel sulfur levels (e.g., >500 ppm S). Additional details of the marine applications of DPFs are summarized in MECA's Locomotive and Marine case study report available at: www.meca.org/galleries/default-file/MECA%20locomotive%20and%20marine%20case%20study%20report%201006.pdf.

Diesel Oxidation Catalysts (DOCs) – DOCs are a well proven technology for oxidizing gaseous pollutants and toxic hydrocarbon species present in the exhaust of diesel engines. DOCs are also effective at reducing diesel PM emissions through the catalytic oxidation of soluble hydrocarbon species that are adsorbed on soot particles formed during the combustion process. DOCs can also oxidize NO present in the engine exhaust to NO_2. This NO_2 can then be used to oxidize soot captured on a DPF at relatively low exhaust temperatures (so-called passive filter regeneration) or to improve the low temperature performance of SCR catalysts by providing a more kinetically variable mixture of NO and NO_2 to the SCR catalyst.

Over two million oxidation catalysts have been installed on new heavy-duty highway trucks since 1994 in the U.S. These systems have operated trouble free for hundreds of thousands of miles. Many new 2007-compliant heavy-duty trucks offered for sale in the U.S. and Canada include an oxidation catalyst upstream of a catalyzed diesel particulate filter in order to help reduce PM emissions to levels below 0.01 g/bhp-hr. Oxidation catalysts have been used on millions of diesel passenger cars in Europe since the early 1990s and oxidation catalysts have been installed on over 250,000 off-road vehicles around the world for over 30 years. DOCs include Pt or Pt/Pd catalyst formulations supported on ceramic or metallic substrates. Again, the application of DOCs is facilitated by the use of low sulfur diesel fuel (500 ppm S or lower).

There have been limited demonstration projects evaluating the feasibility of equipping marine engines with DOCs. In 2003, the New York State Energy Research and Development Authority (NYSERDA) initiated a program to collaborate with private ferry operators to demonstrate emission reduction technologies, including DOCs. Two ferries were retrofitted with DOCs: one ferry with a DOC using a fuel-borne catalyst was estimated to achieve NOx reductions of 5 percent with ultra-low sulfur diesel and PM reductions of 50 percent; the other ferry equipped with a DOC was estimated to achieve PM reductions of 40 percent. NYSERDA issued a program report on their private ferry demonstration program in September 2006 (see www.nyserda.org/default.asp). DOCs have also been installed on passenger ferries operating in Hong Kong. In Texas, a recent marine diesel engine retrofit demonstration, sponsored by the Texas Commission on Environmental Quality's New Technology Research and Development (NTRD) program, combined engine modifications with a DOC to achieve both PM and NOx reductions (see www.tercairquality.org/NTRD/About/).

Additional details of the marine applications of DOCs are summarized in MECA's Locomotive and Marine case study report available at: www.meca.org/galleries/default-file/MECA%20locomotive%20and%20marine%20case%20study%20report%201006.pdf.

In their ANPRM, EPA notes that NOx reductions may be possible through the combination of seawater scrubbers and technologies that oxidize NO exhaust emissions to NO_2. NO_2 is water soluble and can be effectively removed using water-based scrubber technology. DOCs can be effective NO oxidation catalysts and could be combined with a seawater scrubber to effect significant reductions in NOx emissions from the exhaust of large marine diesel engines. Some demonstrations of this combined DOC + seawater scrubber are planned in the near term. Due to the sulfur sensitivity of the NO oxidation catalyst, the performance of such a combined system would be impacted by the fuel sulfur levels used by the marine engine. Maximum NO oxidation performance and DOC durability would be favored by low (<500 ppm) or ultra-low (<50 ppm) sulfur fuels. Periodic desulfation of the DOC using, for example, a non-catalytic fuel reformer might also make such a DOC + seawater scrubber approach viable on higher sulfur fuels. Total NOx reduction efficiencies of such a combined system would depend on the conversion rate of NO to NO_2 over the DOC but could be in the range of 50 percent NOx reduction.

Selective Catalytic Reduction (SCR) Technology – SCR technology is a proven NOx control strategy. SCR has been used to control NOx emissions from stationary sources for over 20 years using either ammonia or urea injection ahead of the SCR catalyst to serve as the reductant that reacts with NOx in the lean diesel operating environment. The experience from stationary applications of SCR technology can be applied to marine diesel installations due to the similar, non-transient modal operating conditions employed in both applications. Stationary demonstrations range from diesel back-up generators, gensets, and stationary engines used on large construction cranes. MECA has summarized this stationary diesel engine experience in a case study report available at: www.meca.org/galleries/default-file/Stationary%20Engine%20Diesel%20Retrofit%20Case%20Studies%200807.pdf.

More recently, SCR systems have been applied to mobile sources, including trucks, off-road equipment, and marine vessels. Applying SCR to diesel-powered engines provides simultaneous reductions of NOx, PM, and HC emissions. Open loop SCR systems can reduce NOx emissions from 75 to 90 percent. Closed loop systems on stationary engines have achieved NOx reductions of greater than 95 percent. Modern SCR system designs have been detailed for mobile source applications that combine highly controlled reductant injection hardware, flow mixing devices for effective distribution of the reductant across the available catalyst cross-section, durable SCR catalyst formulations, and ammonia slip clean-up catalysts that are capable of achieving and maintaining high NOx conversion efficiencies with extremely low levels of exhaust outlet ammonia concentrations over thousands of hours of operation.

The majority of heavy-duty engine manufacturers are offering urea-SCR systems in highway truck applications to comply with Euro IV and V emission regulations in Europe, with more than 100,000 of these European SCR-equipped trucks already in service. Engine manufacturers here in North America are also seriously considering combined DPF+SCR system designs for complying with EPA's 2010 heavy-duty highway emission standards. A number of combined DPF+SCR system demonstration projections have been completed or are in progress on highway trucks both here in the U.S. and Europe. DOC+SCR systems are also being used commercially in Japan for new diesel trucks by several engine manufacturers to comply with Japan's 2005 standards for new diesel trucks. Several technology providers are developing and demonstrating retrofit SCR systems for both on-road trucks and off-road equipment that combine SCR catalysts with either DOCs or DPFs. In these highway diesel engine applications that combine catalyst-based DPFs or DOCs with an SCR catalyst, vehicles are operated on ultra-low sulfur diesel fuel to enable the use of catalysts to achieve significant and durable PM reductions.

Since the mid-1990s, SCR technology using a urea-based reductant has been safely installed on a variety of marine applications in Europe, including auto ferries, cargo vessels, military ships, and tugboats, with over 300 systems installed on engines ranging from approximately 450 KW to over 10,000 kW. Many of these systems reduce NOx emissions from their vessels to under 1 g/kWh, with some applications operating at below 0.5 g/kWh NOx. The marine diesel SCR experience includes installation on both large 2-stroke and 4-stroke marine diesel engines. In most applications, vessels equipped with SCR systems have been successfully operated on marine fuels with up to 1.5% sulfur levels (15,000 ppm). SCR systems on stationary engine applications have seem some limited operation on fuels with sulfur levels as high as 3.5% (35,000 ppm S).

Urea is the preferred reductant in these marine diesel installations, with urea consumption reported to be in the 4-5 gallons/hour/MW of engine power for a 40 percent urea in water solution. Nearly all of these marine SCR installations have employed vanadia/titania-based SCR catalyst formulations. In many cases, these marine diesel SCR installation have placed the SCR catalysts downstream of the engine's turbocharger, but there are also cases where the SCR catalysts have been installed upstream of the turbocharger to provide a better match between the exhaust temperature and the SCR catalyst operating window required to achieve a target NOx reduction. Some typical performance and operating conditions for SCR systems installed on ocean-going vessels are detailed in Table 1 below (supplied by a MECA member).

Table 1. Typical Marine Diesel SCR Performance and Operating Conditions

Performance	
NOx Reduction	90 - 99% at MCR
HC/CO Reduction	80 - 90% at MCR
Soot Reduction	30 - 40% at MCR
Noise Reduction	30 - 35 dB(A)
Operation	
Temperature Span	480 - 985 °F
Fuel	MDO/HFO
Installation	
Weight	Silencer +30 - 60%
Volume	Silencer +/- 20%
Consumables	
Urea Solution (40%)	4 - 5 gal/h (per MW)
Catalyst Life Span	10,000 - 40,000 h

(Notes: MCR: maximum cruise rating of the engine; MDO: marine distillate oil; HFO: heavy fuel oil)

In marine applications, SCR minimum operating temperatures are dictated by fuel sulfur levels and the temperatures that minimize the formation of sulfates on the catalyst surfaces. At relatively low fuel sulfur levels (1,000 ppm S), vanadia/titania-based SCR catalysts can operate as low as 260 °C with minimal sulfate formation. At fuel sulfur levels of 10,000 ppm S, this same SCR catalyst formulation minimum operating temperature rises to around 320 °C to avoid minimize sulfate formation. To avoid plugging the SCR catalyst with carbon soot or other inorganic deposits, marine systems have also employed ultrasonic or pulse jet-based soot blowers. As indicated in Table 1, SCR catalyst life spans in marine applications can be 40,000 hours or even longer dependent on operating conditions and catalyst system design parameters. Vanadia/titania-based catalysts used in marine SCR applications are capable of extended operation at exhaust temperatures as high as 530 °C before catalyst thermal degradation becomes an issue. As stated in EPA's ANPRM, large marine diesel exhaust temperatures are typically maintained below 450 °C to minimize engine exhaust valve impacts from corrosion or fouling from fuel-related impurities.

In addition to these written comments, MECA is also submitting a separate attachment of presentation slides that were provided to the U.S. EPA in a meeting held in the EPA offices in Ann Arbor, MI in November 2004 that detail SCR experience on marine vessels. Included in these slides are typical SCR performance and operational information reported by one MECA member company with extensive experience in the design and operation of SCR systems on large marine vessels operating primarily in Northern Europe. This same MECA member company has also provided to MECA a listing of SCR marine installations they have been completed since 1995 that includes more than 150 SCR systems installed on more than 40 vessels (propulsion and auxiliary engines). A copy of this SCR marine installation listing is also provided as a separate attachment to MECA's comments.

The Port Authority of New York and New Jersey has recently conducted an innovative pilot project to demonstrate diesel emission reduction technologies on a Staten Island ferry. The ferry was retrofitted with DOC+SCR systems on its two main, four-stroke propulsion engines. Emissions testing observed on the ferry showed NOx reductions that typically exceeded 94% during ferry cruise modes. In this project, the ferry engines were fueled with No. 2 diesel fuel with fuel sulfur levels in the 300-350 ppm range. Additional details on this Staten Island ferry project are available at:
www.mjbradley.com/documents/Austen_Alice_Report_Final_31aug06.pdf.

The aforementioned U.S. ferry project, along with other operational, marine SCR installations on ocean-going vessels from outside the U.S., provides firm evidence that SCR systems can be engineered to meet rigorous marine industry conditions and safety standards. Some of these marine SCR systems have been operating since the 1990s with high NOx conversion efficiencies and no reported safety-related issues. Given the significant experience base with SCR installations on large marine vessels over the past fifteen years (>100 marine vessels with more than 300 SCR installations), MECA believes that the implementation of EPA's proposed Tier 3 NOx levels for new Category 3 marine diesel engines could be accelerated and could occur within three years following the implementation of proposed Tier 2 standards (e.g., in the 2014 timeframe assuming that Tier 2 standards are implemented as soon as 2011).

Conclusion

In closing, MECA supports EPA's proposed emission standards for Category 3 marine diesel engines. The two-step proposal put forward by EPA in their ANPRM provides important PM and NOx reductions in the near-term through improvements in engine technology and the use of lower sulfur fuels, and significant long-term NOx reductions through the use of proven, high NOx conversion efficiency SCR catalyst technology for large marine engines used on ocean-going vessels. The significant and growing experience base with the use of SCR on large marine diesel engine applications should allow for an accelerated introduction of EPA's proposed Tier 3 NOx standards in the 2014 timeframe. Continued development of SCR catalysts and SCR systems by major emission control technology suppliers for use on new highway, off-road, and stationary diesel engines and vehicles in the U.S., Europe, and Japan will provide a platform for future improvements in the performance, reliability, and cost of these systems in large marine diesel engine applications. Our industry has a strong commitment to SCR technology for mobile source applications and stands ready to work with engine manufacturers on large marine diesel engine applications.

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