WRITTEN COMENTS
OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE
U.S. ENVIRONMENTAL PROTECTION AGENCY'S
CONTROL OF EMISSIONS OF AIR POLLUTION FROM NEW LOCOMOTIVE ENGINES AND NEW MARINE COMPRESSION-IGNITION ENGINES LESS THAN 30 LITERS PER CYLINDER NOTICE OF PROPOSED RULEMAKING

July 2, 2007

MECA is pleased to present testimony in support of EPA's proposals covering future emission standards for locomotive and marine diesel engines. We believe an important opportunity exists to significantly reduce emissions from new locomotive engines and new marine compression-ignition engines less than 30 liters per cylinder by utilizing an engineered systems approach that incorporates and combines advanced engine designs, advanced emission control technology, and ultra-low sulfur diesel fuel.

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" cars and trucks 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, such as diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), NOx adsorber catalysts, and selective catalytic reduction (SCR) systems, are commercially available today. These 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. There is already growing experience with these "clean diesel" emission control technologies on marine and locomotive diesel engines. These marine and locomotive diesel engine applications pose unique operating environments and challenging packaging envelopes for emission control technologies, but over the past 30 years our industry has accepted and met every challenge in the design and optimization of emission control systems used on mobile source engines that range from small handheld equipment to large off-road equipment.

MECA strongly believes that many of the emission control technologies and strategies that are either already in commercial use or nearing commercial practice for light-duty diesel vehicles meeting EPA's Tier 2 standards, commercialized or under development to meet EPA's 2007-2010 heavy-duty highway diesel engine standards, and under development to meet EPA's

Tier 4 nonroad diesel engine standards will be applicable to locomotive and marine diesel engines in the 2015 timeframe to meet their proposed Tier 4 locomotive and marine diesel emission standards.

MECA has reviewed in detail EPA's NPRM regulatory impact analysis concerning the technical feasibility of catalyst-based PM and NOx controls for achieving their proposed Tier 4 standards for locomotives and marine diesel engines. EPA's technical analysis is strongly supported by available data and experience with catalyst-based exhaust emission controls from the automotive, truck, locomotive, and marine industries. MECA stongly supports EPA's conclusions that their proposed Tier 4 standards for locomotive and marine diesel engines are technically feasible.

Emission Control Technologies for Locomotive and Marine Diesel Engines

MECA would like to provide specific comments on the experience base with diesel particulate filters, diesel oxidation catalysts, and SCR catalysts since these emission control technologies were cited by EPA in their NPRM regulatory impact analysis for their potential in achieving the proposed Tier 4 locomotive and marine diesel standards.

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 this year here in the U.S., all new heavy-duty diesel highway engines are 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% 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. Similar to the highway and off-road diesel application areas, EPA has already put regulations in place requiring the use of ultra-low sulfur diesel fuel in locomotive and marine diesel engines (starting in 2012), an important enabler for the use of catalyst-based PM control technologies. These 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.

Wall-flow filters in addition to trapping soot also trap inorganic ash constituents present in the exhaust stream, chiefly associated with lubricant additive packages. Regular maintenance of wall-flow filters to remove accumulated ash is necessary to keep engine backpressures at acceptable levels. However, through the use of low-ash containing lubricants, improved engine designs that minimize lubricant consumption, proper filter substrate sizing, and novel filter substrate cell designs (e.g., asymmetric inlet and outlet cell sizes), ash cleaning intervals can be extended to many thousands of hours of operation. Some engine manufacturers expect maintenance intervals for filters equipped on new 2007 heavy-duty trucks to reach 300,000 miles or more in Class 8 long haul trucks. MECA published a report on filter maintenance practices and experience in 2005. This report is available on the MECA website at: www.meca.org/galleries/default-file/Filter_Maintenance_White_Paper_605_final.pdf.

In the nonroad diesel engine application area, DPFs have been successfully installed and used on thousands of mining, construction, and materials handling equipment where vehicle integration has been challenging. Particulate filters, many employing active regeneration strategies such as fuel burners or electrical resistance heaters, have also been used on over 200 locomotives in Europe since the mid-1990s, providing in excess of an 85 percent reduction in particulate matter emissions. Some of these systems have been operating effectively for over 650,000 kilometers. A limited number of these active DPF systems have also been safely equipped on marine vessels in Europe to control PM.

Several demonstration projects have been, or are being conducted in the U.S., to evaluate the feasibility of equipping locomotive and marine 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 DPF systems, similar to those equipped on European locomotives, have been retrofit on two 1500 hp switcher locomotives. These two switchers are now operating in rail yards in southern California as part of an industry demonstration program. In another California demonstration project, DPFs will be demonstrated on two commuter rail locomotives operating between Oakland and Sacramento. Additional details of these marine and locomotive 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. ARB has also held workshops in 2006 and 2007 that detail the experience with DPFs on locomotives. Presentation slides shown at these ARB workshops are available at: www.arb.ca.gov/msprog/offroad/loco/loco.htm.

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% 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 been verified by the California Air Resources Board as a Level 2 retrofit device (50-85% PM reduction) on a range of highway diesel engines, have been used by one engine manufacturer (MAN) in Europe for complying with Euro 4 heavy-duty diesel PM limits, and are available in Europe as a retrofit PM technology for light-duty diesel vehicles. Most recently, this metal substrate filter design has been introduced by DaimlerChrysler 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.

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. Both the oxidation of soluble PM species and NO oxidation pathways could be useful in meeting the proposed Tier 4 locomotive and marine diesel standards.

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 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.

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. 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.

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 200 systems installed on engines ranging from approximately 450 to over 10,000 kW. 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. Additional details on this Staten Island ferry project are available at: www.mjbradley.com/documents/Austen_Alice_Report_Final_31aug06.pdf. This ferry project along with other operational, marine SCR installations provides firm evidence that SCR systems can be engineered to meet rigorous marine industry safety standards. Some of these marine SCR systems have been operating since the 1990s with no reported safety-related issues.

As discussed in the EPA technical feasibility document, SCR catalysts formulations based on vanadia-titania and base metal-containing zeolites have been commercialized for both stationary and mobile source applications. The maximum NOx conversion window for SCR catalysts is a function of composition. Base metal zeolite SCR catalysts, in particular, have been selected, and are continuing their development, for applications that require NOx performance and durability under higher exhaust operating temperatures that may be encountered in some mobile source applications that combine a DPF upstream of an SCR catalyst (as would likely be the case for locomotive and marine diesel engines to comply with EPA's proposed Tier 4 standards). Base metal zeolite SCR catalysts have been commercially applied to stationary power generation applications since the mid-1990s. One MECA member has supplied zeolite-based SCR catalysts into a number of power generation applications. Included in this experience are examples of zeolite-based SCR catalysts that have operated in these stationary power generation applications for four years or more (more than 25,000 hours of operation) without catalyst replacement and delivered NOx conversion efficiencies in excess of 90%. This extended operation included SCR catalyst temperatures in excess of 540^{o}C through much of the four plus years of operation.

For low temperature NOx conversion efficiency, emission control system design engineers have a number of options available, including the composition of the SCR catalyst itself (e.g., Cu-zeolite SCR catalyst formulations typically have better low temperature performance than Fe-zeolite SCR catalyst formulations; e.g., see SAE paper no. 2007-01-1575), control of the ratio of NO_2 to NO present at the inlet of the catalyst, and improving the urea decomposition process at low exhaust temperatures. The impact of NO_2/NO ratio on low temperature performance of a Fe-zeolite SCR catalyst is documented in EPA's NPRM regulatory impact analysis. Higher ratios of NO_2/NO at the inlet of this zeolite-based SCR catalyst significantly improve NOx conversion efficiency at inlet gas temperatures between 150 and 250°C. An oxidation catalyst function upstream of the SCR catalyst (e.g., a DOC or catalyzed DPF) can be used to oxidize NO to NO_2 and improve low temperature SCR catalyst performance.

NPRM Request for Detailed Technical Comments

The EPA NPRM includes a request for detailed technical comments on questions provided to EPA by a stakeholder. These questions are specific to the proposed Tier 4 standards and the use of catalyst-based controls to achieve these proposed emission levels. MECA provides the following comments to these questions.

1. Zeolite SCR Performance/Durability – The available database of information on zeolite-based SCR catalysts shows that they are capable of maintaining high NOx conversion efficiencies at space velocities in the range of 40,000/hr at extended operations in 600°C exhaust temperatures. EPA includes some recent references that support this statement in their regulatory impact analysis included with the NPRM. Data provided to MECA by one of its member companies that is currently offering zeolite-based catalysts for sale in Europe for truck applications and developing zeolite-based catalysts for U.S. 2010 heavy-duty applications indicates that a zeolite-based catalyst maintains approximately 90% NOx conversion efficiency in a simulated diesel exhaust stream at exhaust temperatures ranging between 250 and 550°C after hydrothermally aging the catalyst for up to 2000 hours at 600°C. In this study, the zeolite-based SCR catalyst was aged in an air stream that contained 10% water vapor and 20 ppm sulfur dioxide. NOx conversion performance was measured in a simulated diesel exhaust stream with a NO/NO_2 ratio of 1/1 and a space velocity of 60,000/hr (a 50% higher space velocity condition compared to EPA's Tier 4 locomotive SCR design assumption). NOx conversion efficiency of the zeolite-based SCR catalyst was measured in a relatively fresh state and after 800, 1600, and 2000 hours of hydrothermal aging. No degradation in NOx conversion efficiency in the 250-550°C inlet exhaust temperature range was observed between fresh and aged catalysts.

In another example of zeolite-based SCR performance and durability, MECA's European affiliate association, the Brussels-based Association of Emissions Control by Catalyst (AECC, www.aecc.be), has recently completed a heavy-duty Euro VI demonstration program on a modern, low-NOx U.S. 2007-class diesel engine (7.5 liter engine displacement). In this program, an advanced diesel emission control system including a DOC + catalyst-based DPF (14 liter filter volume) and a urea-SCR zeolite-based catalyst (14 liter catalyst volume) + ammonia slip catalyst was evaluated for emissions performance following 200 hours of oven aging of the catalyst components at 600°C. Over the European Steady-State Cycle (ESC), this aged system reduced NOx emissions by approximately 85% and PM mass emissions by more than 90%. Additional details of this AECC test program will be publicly released later this summer.

Laboratory evaluations reported by workers at Ford in SAE paper no. 2007-01-1575 provide evidence that zeolite-based SCR catalysts can maintain high NOx conversion efficiencies after hydrothermal aging at temperatures above 600°C. In this study, both Cu-based and Fe-based SCR catalysts were evaluated. NOx conversion efficiency curves versus inlet gas temperature measured at a space velocity of 30,000/hr showed minimal degradation after hydrothermally aging the SCR catalysts for 2, 27, and 64 hours at 670°C. In these same studies, one hour hydrothermal aging of a Cu-zeolite SCR catalyst at 750^{o}C or one hour of hydrothermal aging of a Fe-zeolite SCR catalyst at 900^{o}C resulted in no significant NOx performance degradation relative to 64 hours of hydrothermal aging at 670^{o}C. In the EPA NPRM regulatory impact analysis, EPA includes data from Ford showing NOx conversion efficiency for a Fe-zeolite SCR catalysts after various thermal aging treatments. These results also show no significant NOx performance difference between the SCR catalyst aged 20 hours at 700^{o}C, 40 hours at 700^{o}C, or 20 hours at 725^{o}C for inlet gas temperatures above 250^{o}C and a space velocity of 30,000/hr.

Results shown by one MECA member (a major catalyst manufacturer for mobile sources) at the SAE Heavy-Duty Diesel Emissions Control Symposium held in Gothenburg, Sweden on September 20-22, 2005 support the results reported by Ford. In their results, this MECA member showed NOx efficiency curves versus inlet gas temperature results for a Fe-zeolite-based SCR catalyst in a relatively fresh state and after hydrothermal aging at 700^{o}C for 50 hours. A small amount of NOx conversion efficiency degradation was observed after hydrothermal aging at 700^{o}C for inlet gas temperatures in the range of 300-500^{o}C. In this case, the hydrothermally aged SCR catalyst demonstrated NOx efficiencies of approximately 85% or greater over this inlet gas temperature range.

The performance of zeolite-based SCR catalyst is not expected to be impacted by operating in a locomotive or marine diesel exhaust that contains a 0.03 g/bhp-hr PM level (the proposed Tier 4 PM standard for these engines). Fe-zeolite SCR catalysts have recently been commercialized in Japan for heavy-duty truck applications. These Japanese heavy-duty truck applications combine a DOC in front of the SCR catalyst and operate at PM levels at the inlet to the SCR catalyst that are considerably higher than 0.03 g/bhp-hr with no reported problems (see SAE paper no. 2005-01-1860).

2. Mechanical and Environmental Concerns – Zeolite-based SCR catalysts are expected to withstand the mechanical and ambient conditions required for locomotive applications. SCR systems have already been designed or are being designed to deal with mechanical and thermo-mechanical conditions associated with passenger cars, trucks, and marine vessels. These mechanical and ambient conditions are expected to be no more severe for locomotive applications. Durability under thermo-mechanical environments depends on both the physical strength of the catalyst element and the design of the packaging system that contains the catalyst element(s). MECA members have considerable experience in packaging catalysts for severe thermo-mechanical environments. System design engineers can utilize a variety of tools, including hot vibration testing and engine testing, to design and validate effective system designs that can withstand the thermo-mechanical environment present in the exhaust. Locomotives and marine diesel engines will include air filtering elements designed to protect the engine and these same air filter elements will provide protection to the catalysts equipped on these engines from large particulates that might be present in the inlet combustion air to the engine. MECA understands that some of the concerns raised for exposure to salt fog, sand, china clay, and silicon flour are military specifications for external surfaces of vehicles and are not pertinent to catalysts contained within the exhaust stream of a locomotive.

3. DOC Durability – DOCs are a well proven, durable catalyst-based technology that have accumulated millions of miles of service on light-duty and heavy-duty vehicles. In particular, the ability for DOCs to oxidize NO to NO_2 is a critical pathway to the soot regeneration characteristics of catalyst-based DPFs that rely on the passive regeneration of soot. In some designs, these catalyst-based DPFs include a DOC upstream of either an uncatalyzed or catalyzed wall-flow ceramic filter. The literature includes numerous references to the use of retrofit catalyzed filters that feature a DOC+DPF configuration where the DOC is used to oxidize NO to NO_2 to facilitate soot regeneration at relatively low exhaust gas temperatures in the range of 200 to 350^{o}C. In some cases, these DOC+DPF retrofit passive filters have been in service for many years and hundreds of thousand of miles of operation. SAE papers nos. 2000-01-0480 and 2004-01-0079 are two references that provide evidence that passive soot regeneration facilitated by NO oxidation over a DOC is maintained after many thousands of hours of operation.

4. Low Ammonia Slip – MECA agrees with EPA's technical discussion concerning the technical feasibility of designing SCR systems with low ammonia slip characteristics. Low ammonia slip SCR systems (e.g., 20 ppm or less ammonia peak concentrations in the exhaust exiting the SCR catalyst) have been and can be designed for locomotive or marine diesel applications. Achieving low ammonia slip includes proper sizing of the SCR catalyst and the design and control of the urea dosing system. Work completed as part of the large U.S. Department of Energy Advanced Petroleum-Based Fuels-Diesel Emission Control Program includes evaluations of two different DPF+SCR systems on a modified heavy-duty highway engine. In these systems, with only open loop control of the urea-dosing systems and the use of ammonia slip catalyst at the exit of the SCR catalysts, average ammonia levels measured in the exhaust during transient and steady-state testing were 6 ppm or less after engine aging these systems for 6000 hours (see the Southwest Research Institute presentation from the August 2005 DEER Conference held in Chicago, IL). In the case of performance measured over the Federal heavy-duty transient test cycle, both of these aged systems showed ammonia slip levels of less than 1 ppm on average across the transient test cycle.

As cited by EPA in their regulatory impact analysis, closed-loop control of SCR systems is now being developed for U.S. light-duty and heavy-duty diesel vehicles and will be introduced into the market between 2008 and 2010. These closed-loop control systems will operate under conditions that maximize NOx conversion efficiencies while minimizing ammonia slip. In addition, catalyst manufacturers have available and continue to develop ammonia slip catalysts that can be placed after the SCR catalyst to selectively convert ammonia to nitrogen. Ford workers detail their own evaluations of ammonia slip catalysts in SAE paper nos. 2007-01-1572 and 2007-01-1581. In their abstract of SAE paper no. 2007-01-1572, these researchers state, "Current state of the art NH_3 slip catalysts are shown to be capable of removing nearly all NH_3 at temperatures above 225^{o}C at low (80,000/hr) space velocities (SV) with good selectivity to N_2." These results provide strong evidence that SCR catalysts can be designed and operated on locomotives with extremely low or near zero ammonia slip.

5. NOx sensors – NOx sensors are commercially available from one MECA member and have been used on light-duty vehicle applications of lean-burn, gasoline direct injection engines to control NOx adsorber-based catalysts. This NOx sensor technology utilizes electrochemical oxygen cells to simultaneously determine oxygen and NOx concentrations in an exhaust stream. The current generation of NOx sensors produced by this manufacturer recently successfully completed a 6000-hour durability test on a heavy-duty diesel engine equipped with a DPF + urea

SCR system. Details of this 6000-hour durability test are contained in SAE paper no. 2005-01-3793. This NOx sensor design currently has engine-aged accuracy for NOx concentrations in the 0-100 ppm range of +/- 15%. The manufacturer of this NOx sensor technology expects to introduce a next generation sensor with +/- 10% aged accuracy in 2010 and is targeting +/- 5% accuracy by 2013 with a clearly defined development path. NOx sensors are also under development by other manufacturers for applications on both on-road and off-road diesel engines to control catalyst-based NOx emission control systems and to provide diagnostic information concerning the performance of these systems. MECA expects suitable NOx sensors to be available for use on locomotives and marine diesel engines in time for Tier 4 applications.

6. Locomotive vs. Marine Diesel SCR Applications – SCR catalyst performance and durability issues are generally independent of the diesel engine application under consideration. Catalyst performance will be largely a function of inlet exhaust gas conditions of temperature and gas composition, the space velocity that the catalyst operates at, the composition of the catalyst, the levels of potential poisons present in the exhaust stream, and the maximum temperature that the catalyst is exposed to during the full useful life period. These catalyst boundary conditions, although not completely equivalent between locomotive and marine diesel engines, are within the performance windows of existing SCR catalyst formulations. Other than unique packaging constraints, MECA firmly believes that durable SCR catalyst compositions will be available to allow both locomotive and marine diesel engines to comply with EPA's proposed Tier 4 standards in the 2015 timeframe. Both Tier 4 locomotive and marine diesel SCR applications will benefit from continued development efforts on SCR systems that will be driven by much higher volume applications on light-duty vehicles, heavy-duty vehicles, and off-road diesel-powered equipment.

Other Diesel Emission Control Technology Comments

The continued development and commercialization of durable DOCs, DPFs, and SCR catalyst systems is an important focus of the emission control industry and their customers in the engine, equipment, and vehicle manufacturing industries. But the new "clean diesel" world of technologies also includes other options for catalyst-based controls for NOx. NOx adsorber catalysts are in commercial production on a number of light-duty and medium-duty diesel vehicles offered by Toyota, Hino, Mercedes, and Chrysler/Cummins. Additional launches of NOx adsorber catalysts have also been announced by Volkswagen on 2008 model year light-duty diesel vehicles in North America. More recently, manufacturers have described NOx-based catalyst systems that combine NOx adsorbers with SCR catalysts. Examples of these combined technology offerings include the BlueTec system currently available on the Mercedes E320 CDI diesel in the U.S. and Honda's dual layer NOx adsorber/SCR catalyst, single converter technology approach targeted for 2009 light-duty diesel applications in North America (see SAE paper no. 2007-01-0239). In these combinations of NOx adsorbers and SCR catalysts, the primary NOx control pathway is through the NOx adsorber catalyst with the SCR catalyst providing incremental NOx conversion with the help of ammonia produced by the NOx adsorber catalyst during oxygen deficient regeneration operations. This ammonia is stored on the SCR catalyst and reacts with NOx during normal lean operating modes. In this manner, these combined systems do not need to use a separate reductant fluid such as urea/water mixtures to facilitate selective NOx conversion over the SCR catalyst. These combination NOx adsorber/SCR catalyst system designs can also employ catalytic fuel reformers (see for example

SAE paper no. 2006-01-3552) to provide an effective reducing environment for regenerating or desulfating the NOx adsorber function present in the system.

The clean diesel technology thrust has also spawned a variety of new sensor technologies that can be used to help control catalyst-based emission control technologies like SCR catalysts or NOx adsorber catalysts or be used for diagnostic purposes to determine if these systems are operating within design constraints. Examples of sensor developments include NOx sensors (see NOx sensor section above), ammonia sensors, and urea quality sensors. NOx sensors and urea quality sensors are already seeing commercial application on vehicles in Europe and Japan.

Reviews of diesel engine and diesel emission control technologies are available through a series of SAE papers authored by Dr. Timothy Johnson of Corning Incorporated. These annual review papers provide a large number of technical paper references and summaries of the technology advancements that are rapidly changing the nature of diesel engines in on-road and off-road applications. The most recent reviews provided by Dr. Johnson can be found in SAE paper nos. 2007-01-0233 and 2006-01-0030. The diversity of technology developments included in these review papers speaks to the significant breadth and volume of activity aimed at clean diesel technologies, including advanced diesel emission control technologies of all types for reducing PM and NOx emissions.

Conclusion

While we recognize that the proposed new Tier 4 locomotive and marine diesel engine standards present engineering challenges, we also believe those challenges can and will be met. The key will be to employ the systems approach identified in EPA's proposal consisting of the further evolution of locomotive and marine diesel engine designs, the use of advanced emission control technology, such as diesel particulate filters and SCR catalyst systems, the use of ultra-low sulfur diesel fuel, and the use of low ash and sulfur-containing lubricants. MECA has reviewed EPA's Tier 4 technical feasibility discussion presented in their NPRM and agrees with EPA's technical assessments. MECA and its member companies firmly believe that high efficiency and durable diesel particulate filters and SCR catalysts meeting the EPA staff technical assumptions for their proposed Tier 4 standards on locomotive and marine diesel engines will be available in the 2015 timeframe. MECA member companies stand ready to work with locomotive and marine engine manufacturers on understanding current diesel PM and NOx catalyst performance and durability levels, and to begin the application engineering process for future locomotive and marine diesel exhaust emission control systems.

Our industry is convinced that advanced exhaust emission controls that have already begun to usher in the new generation of clean diesel engines used in cars and trucks in the U.S., Europe, and Japan will also allow for significant reductions in both NOx and diesel particulate emissions from locomotive and marine diesel engines in the next decade.

<u>MECA Contact:</u>
Dr. Joseph Kubsh
Executive Director
Manufacturers of Emission Controls Association

1730 M Street, NW
Suite 206
Washington, D.C. 20036
phone: 202-296-4797
e-mail: jkubsh@meca.org