

**WRITTEN COMMENTS OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE CALIFORNIA AIR RESOURCES BOARD'S PROPOSED AMENDMENTS TO
THE LEV III REQUIREMENTS FOR LIGHT-DUTY AND MEDIUM-DUTY
VEHICLES, AND TEST PROCEDURES FOR HEAVY-DUTY ENGINES/VEHICLES**

October 23, 2014

MECA is pleased to provide written comments in support of the Air Resources Board's proposed amendments to the LEV III standards for light- and medium-duty vehicles, and the test procedures for heavy-duty engines and vehicles. These proposals, when finalized, will more completely align ARB's LEV III requirements with EPA's Tier 3 light-duty and medium-duty criteria pollutant emissions standards. This alignment will essentially create for the first time a single, national set of exhaust and evaporative emission standards for light- and medium-duty vehicles. LEV III and Tier 3 vehicle criteria pollutant standards reset the bar for state-of-the-art exhaust and evaporative emission controls for light-duty vehicles through 2025, and provide significant public health benefits to the citizens of California and the rest of the U.S. MECA applauds ARB and EPA for developing a largely unified LEV III/Tier 3 national program that is aligned in time with the light-duty vehicle fuel efficiency/greenhouse gas emission requirements. MECA strongly supports ARB's proposed LEV III actions that harmonize most of the remaining differences with EPA's final Tier 3 regulation, but also leave in place a few remaining important differences between these programs.

MECA is a non-profit association of the world's leading manufacturers of emission control technology for mobile sources. Our members have over 40 years of experience and a proven track record in developing and manufacturing emission control technology for a wide variety of on-road and off-road vehicles and equipment, including extensive experience in developing exhaust and evaporative emission controls for gasoline and diesel light-duty vehicles in all world markets. Our industry has played an important role in the emissions success story associated with light-duty vehicles in the United States, and has continually supported efforts to develop innovative, technology-forcing, emissions programs that have provided important public health benefits here in the U.S. and served as model programs in countries around the globe. The mobile source emission control industry has generated hundreds of billions of dollars in U.S. economic activity since 1975 and supports more than 65,000 U.S. jobs, mostly in product development and manufacturing. ARB's and EPA's LEV III/Tier 3 emissions and fuel standards will provide additional support for the continued development of a thriving U.S. industry focused on a wide range of technologies that can reduce vehicle criteria emissions.

MECA strongly agreed with both ARB and EPA staff's assessment that achieving the LEV III/Tier 3 exhaust and evaporative emission standards and associated emission reductions are both technically feasible and cost-effective. This fact is clearly demonstrated by the millions of SULEV- and PZEV-compliant light-duty vehicles that have been sold in the U.S. market since these near-zero emission, gasoline vehicles were first introduced more than ten years ago. This technology base of advanced three-way catalysts, exhaust hydrocarbon adsorber materials, high cell density substrates, emission system thermal management strategies, secondary air injection

systems, advanced carbon canisters, advanced low fuel permeation materials, and air intake hydrocarbon adsorber materials that have already been commercialized for a variety of PZEV gasoline vehicle applications can be extended and further optimized to allow all light-duty and medium-duty gasoline vehicles to achieve the exhaust and evaporative emission reductions needed to comply with a largely harmonized LEV III/Tier 3 vehicle emission program. On the exhaust side, Tier 3/LEV III emission technologies (including advanced three-way catalysts, advanced high cell density substrates, and hydrocarbon adsorber catalysts) are highlighted in a MECA report entitled: “LEV III and Tier 3 Exhaust Emission Control Technologies for Light-Duty Gasoline Vehicles” (available on MECA’s website, www.meca.org, under Resources >> Reports). A recent SAE paper (SAE paper no. 2011-01-0301) demonstrates how advanced three-way catalysts utilizing high cell density substrates can be combined to achieve Tier 3, Bin 20 or Bin 30, exhaust emission levels on a four-cylinder, light-duty gasoline vehicle. A 2013 SAE paper (SAE paper no. 2013-01-1297) provides insights into recent improvements in performance and durability of hydrocarbon adsorber catalysts. A 2014 SAE paper (SAE paper no. 2014-01-1509) discusses combining advanced three-way catalyst formulations with improved light-off characteristics with hydrocarbon adsorbers to reduce cold-start emissions. These latest generation hydrocarbon adsorber catalysts show improved cold-start hydrocarbon emission reductions with reduced precious metal content compared to earlier generations of hydrocarbon adsorber catalysts. Hydrocarbon adsorber catalysts are available to assist in difficult Tier 3 applications, such as larger weight trucks and SUVs.

Advanced evaporative emission technologies (including advanced carbon canisters and air intake hydrocarbon adsorbers) that are available to meet Tier 3/LEV III evaporative emission standards for light-duty or medium-duty gasoline or flex-fuel vehicles are discussed in the MECA report: “Evaporative Emission Control Technologies for Light-Duty Gasoline Vehicles” (available on MECA’s website, www.meca.org, under Resources >> Reports). MECA worked closely with ARB in developing the LEV III canister bleed emission testing protocol (also included in EPA’s Tier 3 proposal) that provides a cost-effective means of defining the bleed emission performance characteristics of carbon canisters used on light-duty or medium-duty gasoline vehicles. Including this canister bleed emission test procedure in the Tier 3/LEV III requirements ensures that vehicle manufacturers have to meet a minimum canister performance level in complying with the “zero” evaporative standards that California first put in place for PZEV-certified vehicles. As on the exhaust side, the millions of PZEV-certified vehicles operating on U.S. highways today form a solid evaporative technology base that can be extended to all future Tier 3/LEV III light-duty and medium-duty vehicles.

In addition, advanced diesel emission control technologies, including diesel particulate filters (DPFs), lean NO_x adsorber catalysts, and selective catalytic reduction (SCR) catalysts, will be combined with future, advanced diesel engines to allow light-duty diesel vehicles to achieve LEV III/Tier 3 emission limits, including SULEV30/Tier 3, Bin 30 exhaust standards. Two recent research programs have discussed pathways to reaching Tier 3, Bin 30 exhaust standards with a light-duty diesel vehicle. The first of these is the Cummins Advanced Technology Light-Duty Diesel Aftertreatment System (ATLAS) program, sponsored by the U.S. Department of Energy (DOE). Details of this project were presented at the 2012 DOE DEER Conference held in Dearborn, MI (see: www1.eere.energy.gov/vehiclesandfuels/resources/proceedings/2012_deer_presentations.html,

presentation by Mr. Cary Henry, Cummins, Inc.) and included in SAE paper no. 2013-01-0282 that was presented at the April 2013 SAE International Congress in Detroit, MI. Advanced diesel emission control technologies, including a passive lean NO_x adsorber and an SCR-coated DPF that utilizes direct ammonia reductant injection, have been combined in this program with advanced combustion controls on a 2.8 liter, 4 cylinder diesel engine to demonstrate a pathway to Tier 3, Bin 30 exhaust emissions compliance on a full-size, light-duty pick-up truck. A second approach to Tier 3, Bin 30 exhaust levels on a light-duty diesel vehicle was discussed by Southwest Research Institute in SAE papers no. 2013-01-1301 and 2014-01-1552 (presented at the April 2013 and April 2014 SAE International Congresses in Detroit, MI). This project combines advanced diesel combustion technologies, including high temperature glow plugs, with a close-coupled lean NO_x adsorber catalyst + catalyzed DPF emission system to significantly reduce cold-start emissions and provide a pathway to Tier 3, Bin 30 exhaust emission compliance on a 2 liter diesel-equipped sport-utility vehicle.

MECA supports ARB's decision to retain some differences between LEV III and Tier 3 requirements. The most significant of the remaining differences is ARB's 1 mg/mile FTP PM standard that currently starts implementation with model year 2025. MECA strongly supported and agreed with ARB's decision to include a 1 mg/mile particle matter standard for light-duty vehicles over the FTP test cycle in their LEV III requirements. In the Tier 3 final rule, EPA decided only to harmonize with the LEV III 3 mg/mile FTP PM standard and did not include a 1 mg/mile FTP PM standard. The 2012 decision by the European Commission to establish a particle number emission standard for light-duty vehicles powered by gasoline direct injection (GDI) engines as a part of their Euro 6 light-duty emission standards provides a more stringent particle emission limit for these GDI vehicles in the same time frame as the Tier 3/LEV III 3 mg/mile PM standard (phase-in for the LEV III/Tier 3, 3 mg/mile PM standard starts in 2017 and is fully phased-in with the 2021 model year for LEV III, in 2022 for Tier 3; implementation of the Euro 6 GDI particle number limit of 6×10^{11} particles/km [equivalent to the Euro 5 light-duty diesel particle number limit], measured using the European PMP particle measurement protocol, begins in September 2017; see: ec.europa.eu/enterprise/sectors/automotive/documents/directives/motor-vehicles/index_en.htm). This European light-duty GDI particle number limit, coupled with soon to be finalized real-world driving emission requirements in Europe, will cause auto manufacturers to introduce cleaner technologies, such as advanced fuel injection systems and/or gasoline particulate filters, to comply with the European Euro 6 GDI particle number limit. Auto manufacturers are already working to bring forward early introductions of these ultra-low PM, Euro 6-compliant gasoline engines to the European market in the coming 12 to 18 months (European member states are permitted to introduce tax incentives for early introductions of Euro 6 vehicles prior to the first implementation dates of September 2014 for new models and September 2015 for all passenger car models). This past August a publication from a German environmental organization (the German Traffic Club, VCD, see www.vcd.org) announced that Mercedes became the first European car manufacturer to introduce GPFs on their S500 GDI passenger vehicle. Nearly all auto manufacturers that sell into the European market are working with MECA members on potential applications of particulate filters on gasoline direct injection vehicles.

Gasoline particulate filters (GPFs) are based on the same, wall-flow ceramic filters that have been successfully applied on millions of light-duty and heavy-duty diesel vehicles in

Europe and the U.S. for more than 10 years. The performance and application of these gasoline particulate filters has been highlighted in a number of recent technical publications in both the U.S. and Europe (e.g., SAE paper nos. 2010-01-0365, 2011-01-0814, and 2013-01-0836; SAE paper no. 2013-01-0527 and a 2014 paper published in *Environmental Science & Technology*, both authored by Environment Canada and MECA; technical papers authored by Corning Inc. and NGK at the recent October 2014 Aachen Symposium held in Aachen, Germany). Like diesel particulate filters, gasoline particulate filters are capable of reducing particle emissions by more than 85% over a wide range of particle sizes, including high capture efficiencies for ultra-fine particulates. Like DPFs, GPFs also provide significant reductions in exhaust black carbon emissions, an important short term climate forcing agent (see the Environment Canada/MECA 2014 publication in *Environmental Science & Technology*). The application of a GPF on a four-cylinder gasoline direct injection vehicle is expected to cost approximately \$100 (see ICCT's GPF cost estimate available here: www.theicct.org/estimated-cost-gasoline-particulate-filters), making this emission control technology a cost-effective solution for reducing particulate emissions from future gasoline vehicles. When these filters are properly designed, the impact of a GPF installation on the backpressure and fuel-efficiency of the vehicle has been shown to be minimal.

ARB needs to make sure that these same ultra-low PM, Euro 6 GDI engine/emission technologies are also utilized in the U.S. ARB needs to implement appropriate LEV III particle mass or particle number emission requirements that force manufacturers to utilize best available particle control technologies on future GDI vehicles in the same timeframe that these technologies are utilized in Europe. Effective policies may include moving forward the implementation date for the current LEV III 1 mg/mile FTP PM limit and/or adopting a parallel particle number limit that utilizes a correlation between particle mass, average particle size, and numbers of particle emissions. It is important for California and the United States to continue to set the bar on light-duty vehicle emission standards in order to encourage the development and use of best available control technologies for light-duty vehicles. ARB has a long history of setting technology-forcing vehicle standards based on the public health benefits they provide and this leadership needs to continue with respect to light-duty vehicle particle emission standards. There is growing evidence that particle emissions from engines/vehicles pose a significant public health risk and ARB needs to have effective policies in place that ensure that best available particle filter technologies are utilized on light-duty, medium-duty, heavy-duty vehicles, and off-road diesel engines.

A critically important element to ensuring that future gasoline vehicles will be able to comply with LEV III/Tier 3 emission limits is the use of ultra-low sulfur gasoline (approximately 10 ppm sulfur on average). California imposed strict sulfur limits on gasoline several years ago and now EPA has included ultra-low sulfur limits nationally starting in 2017 as part of their Tier 3 final regulation package. Numerous published studies have documented fuel sulfur-related deactivation of three-way catalysts that are the primary exhaust emission control technology used on light-duty and medium-duty gasoline vehicles. The negative impacts of gasoline fuel sulfur content on catalytic emission controls are highlighted in a newly revised MECA report: "The Impact of Gasoline Fuel Sulfur on Catalytic Emission Control Systems" (available on MECA's website, www.meca.org, under Resources >> Reports). In their final Tier 3 rule, EPA highlights work done with MECA in demonstrating Tier 3, Bin 30 (LEV III SULEV30) emissions on a full

size, V8 Chevrolet Silverado pick-up truck equipped with advanced three-way catalysts that were aged to the equivalent of 150,000 miles of service. This full size pick-up truck demonstrated SULEV30 emissions level with a reasonable compliance margin using 9 ppm sulfur, E10 gasoline (18 mg/mile NMOG+NO_x). Emissions on this truck were more than 50% higher when fueled with 29 ppm sulfur, E10 gasoline (29 mg/mi NMOG+NO_x).

EPA has also released a thorough and well-designed sulfur effects study on 81 in-use Tier 2 light-duty gasoline vehicles that clearly showed significant reductions in criteria pollutants in comparing emissions performance on gasoline with 28 ppm sulfur versus 5 ppm sulfur. Work published in a 2011 SAE technical paper (SAE paper no. 2011-01-0300) shows similar, significant emission benefits on a 2009 model year PZEV vehicle operated with 3 ppm sulfur gasoline versus 33 ppm sulfur gasoline. In this gasoline sulfur effects study, on a 2009 PZEV passenger car, the results clearly show that the underfloor converter used on the close-coupled + underfloor PZEV catalytic converter system was susceptible to sulfur-related performance degradation due to its cooler operating temperatures during the FTP test cycle using a 33 ppm sulfur-containing gasoline. The loss in NO_x performance of this underfloor PZEV converter in successive FTP tests could be recovered to some extent, or avoided to a large degree, by either purging stored sulfur off the underfloor converter with the use of a higher speed and load test cycle (i.e., the US06 test cycle) sandwiched between FTP tests, or using a gasoline with significantly lower sulfur levels (i.e., a 3 ppm sulfur-containing gasoline).

Sulfur deactivation of three-way catalysts negatively impacts the active precious metal catalysts, oxygen storage materials, and other activity promoters found in these sophisticated catalysts. The coverage and negative impacts of sulfur poisons on a three-way catalyst depends, in part, on the temperature history of the catalytic converter(s) found on the vehicle. Fuel sulfur deactivation of three-way catalyst is most apparent at lower exhaust temperatures (e.g., catalyst temperatures of less than about 500 degrees C). Sulfur deactivation of catalysts can be reversed to some degree by exposing catalysts to higher exhaust temperatures. Exhaust temperatures are expected to cool in the future as manufacturers reduce vehicle waste heat to meet future vehicle fuel efficiency/greenhouse gas standards. These cooler catalytic converter operating temperatures cause catalysts to accumulate higher amounts of sulfur poisons with today's gasoline sulfur levels, resulting in higher emission levels of pollutants at the tailpipe, including ozone-forming exhaust pollutants like hydrocarbons and NO_x. Ultra-low gasoline sulfur levels of 10 ppm on average are needed to ensure that manufacturers will be able to meet the SULEV30/Tier 3, Bin 30 fleet average emission standards over their 150,000-mile useful life for the full range of light-duty vehicles that consumers wish to buy and manufacturers want to produce.

In addition to the need for a 10 ppm national average sulfur limit on gasoline for compliance with LEV III/Tier 3 emission standards, the availability of ultra-low sulfur gasoline will also open up opportunities for vehicle manufacturers to develop and commercialize lean gasoline engines that can provide improved fuel economy benefits relative to stoichiometric gasoline engines. A number of manufacturers are offering lean gasoline engine options in Europe and are interested in using this lean combustion approach to meet more stringent, future U.S. fuel economy/greenhouse gas emission standards. Lean gasoline engines will require the use of a lean NO_x emission control technology to comply with LEV III/Tier 3 emission

standards. Lean NOx adsorber catalysts are being used in Europe (where the gasoline sulfur cap is 10 ppm) on lean gasoline engines to reduce NOx emissions from these lean engines. Lean NOx adsorber catalyst performance is significantly impacted by gasoline fuel sulfur levels – the NOx adsorber function of these catalysts also strongly adsorb sulfur constituents present in the exhaust. Ultra-low sulfur gasoline is an important enabler for maximizing the performance of lean NOx adsorber catalysts, minimizing the duration and frequency of NOx adsorber desulfation events, and maximizing the potential fuel economy benefits of lean engine operation. A recent SAE publication (SAE paper no. 2013-01-1299) describes recent efforts to optimize the performance and desulfation characteristics of lean NOx adsorber catalysts that are targeted for a light-duty lean gasoline engine application. A national 10 ppm gasoline sulfur average requirement will provide manufacturers with the opportunity to use lean gasoline engine technology as an option for meeting future ARB/EPA fuel efficiency/greenhouse gas standards.

In summary, there are significant opportunities to reduce both criteria pollutant and greenhouse gas emissions from the transportation sector through the design of fuel-efficient powertrains that include advanced exhaust emission controls for meeting even the most stringent criteria pollutant standards that are included in a largely harmonized LEV III/Tier 3 program. MECA strongly supports ARB’s proposed actions that close most of the remaining differences between LEV III and Tier 3, and establish a largely harmonized national program for reducing criteria pollutants from light- and medium-duty vehicles. ARB needs to maintain its more aggressive LEV III requirements for vehicle particle emissions and ensure that these particle emission standards bring the same best available technology to vehicles in California that manufacturers will be introducing in Europe for future gasoline direct injection vehicles in the 2017 timeframe. MECA believes that advanced emission control systems have a critically important role in future policies that aim to reduce mobile source criteria pollutant and greenhouse gas emissions, and our industry is committed to delivering those emission control technology solutions.

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