

**SUPPLEMENTAL WRITTEN COMMENTS OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S PROPOSAL –
CONTROL OF AIR POLLUTION FROM MOTOR VEHICLES: TIER 3 MOTOR
VEHICLE EMISSION AND FUEL STANDARDS**

Docket ID No. EPA-HQ-OAR-2011-0135

August 22, 2013

MECA is pleased to provide supplemental written comments in support of the U.S. EPA's proposed Tier 3 light-duty vehicle emission and fuel standards. As stated in MECA's earlier written Tier 3 comments, these proposals, when finalized, will 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 the U.S. The proposals will also require the oil industry to produce and sell ultra-low sulfur gasoline that will result in immediate and significant emission reductions from the hundreds of millions of light-duty vehicles operating every day on America's highways, and ensure future fuel-efficient gasoline vehicles can comply with EPA's proposed Tier 3 emission limits. MECA applauds EPA for developing a Tier 3 proposal that will establish a national set of exhaust and evaporative emission standards for light-duty and medium-duty vehicles by largely harmonizing their proposal with California's LEV III requirements.

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. EPA's proposed 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.

In these supplemental comments MECA would like to provide additional information and comments on four important topics: 1) the importance of 10 ppm average sulfur gasoline to meeting proposed Tier 3 emission limits; 2) the synergy between ultra-low sulfur gasoline and the introduction of cost effective, lean-burn, gasoline direct injection technology with improved fuel consumption; 3) costs associated with Tier 3 compliance on gasoline light-duty vehicles; and 4) harmonization with ARB's 1 mg/mile LEV III PM standard.

With respect to the need for a 10 ppm average sulfur gasoline standard, MECA has had the opportunity to review written Tier 3 comments submitted by the American Petroleum Institute (API) and the American Fuel & Petrochemical Manufacturers (AFPM). In these comments API and AFPM argue that EPA did not adequately justify the need for a 10 ppm average sulfur standard for gasoline in EPA's Tier 3 proposal (API & AFPM Tier 3 comments dated June 28, 2013). In their discussion of the technical need for lower gasoline sulfur levels, API and AFPM refer to three emission control technologies that target cold-start emissions on gasoline light-duty vehicles and that EPA noted in their Tier 3 Draft Regulatory Impact Analysis (DRIA) as technologies they expect to be deployed in order to comply with proposed Tier 3 exhaust standards. These three cold-start emission control technologies are hydrocarbon adsorbers, reduced thermal mass catalyst substrates and exhaust piping, and secondary air injection. API & AFPM make the statement in their comments that based on the description of these technologies provided by EPA in their DRIA, it is reasonable to assume that these technologies have little or no sensitivity to fuel sulfur levels. Using this assumption of no fuel sulfur sensitivity, API and AFPM then go on to assume that these sulfur insensitive cold-start technologies could be used to completely eliminate cold-start emissions with today's gasoline fuel sulfur levels. They then go on to show that with zero cold-start emissions of NMOG and NO_x, typical warmed-up emissions are already at a level on light-duty vehicles that would allow proposed Tier 3 emissions of 30 mg/mile NMOG+NO_x to be achieved with a 50% compliance margin without the need for a lower gasoline sulfur level (Figure 2 in the detailed comments section of the API & AFPM, June 28, 2013 Tier 3 comments).

This analysis of a Tier 3 compliance pathway that utilizes sulfur insensitive cold-start technologies is severely flawed in its initial assumption that cold-start technologies like hydrocarbon adsorbers, low thermal mass catalyst substrates/exhaust components, and secondary air injection are not sensitive to fuel sulfur levels. Each of these cold-start technologies still relies on a precious metal-based catalyst to oxidize hydrocarbons or reduce NO_x, and these precious metal-based catalysts have well known sensitivities to fuel sulfur levels. Hydrocarbon adsorbers utilize zeolite-based materials to adsorb exhaust hydrocarbon constituents under relatively cold exhaust conditions and then release these stored hydrocarbon species at elevated exhaust temperatures. Once an adsorber releases these hydrocarbons back into the exhaust gas, a precious metal-based catalyst is required to oxidize these hydrocarbon species. The adsorber primarily functions as a temporary hydrocarbon "sponge" that provides time for the catalyst to heat-up and "activate" the catalytic oxidation reaction. The catalyst must "light-off" or activate to oxidize hydrocarbons during the cold-start portion of the emissions test cycle. There is an extensive body of literature that clearly shows that precious metal-based catalyst hydrocarbon light-off characteristics are negatively impacted by fuel sulfur levels. As sulfur accumulates on the active catalyst surface, the hydrocarbon light-off temperature increases. Hydrocarbon adsorber effectiveness in reducing cold-start hydrocarbon emissions is tied to the catalyst hydrocarbon light-off properties which, in turn, are impacted by fuel sulfur levels.

In a similar manner, cold-start technologies like low thermal mass substrates and secondary air injection help to accelerate the heat-up of the active catalyst but the catalyst is still the agent that facilitates the chemical reactions of hydrocarbon oxidation and reduction of NO_x. Just as in the case of hydrocarbon adsorbers, the catalyst still needs to be activated or lit-off for the oxidation and reduction reactions to occur. Low thermal mass substrates or exhaust piping

and secondary air injection only impact the catalyst heat-up process. The catalyst still needs to accomplish the oxidation and reduction reactions and the catalyst activity/light-off temperature is impacted by fuel sulfur levels. An example of this sulfur dependence is found in SAE paper number 2013-01-0300 (authored by Ball and Moser) that reports on the sulfur sensitivity of FTP NOx emissions using a 2009 model year Chevy Malibu PZEV vehicle. This Malibu PZEV vehicle utilizes secondary air injection and high cell density, low thermal mass substrates. Figure 11 of this paper summarizes the NOx FTP emission performance results for each portion of the test cycle: Bag 1 (cold-start), Bag 2 (warmed-up performance), and Bag 3 (hot start performance). For tests run with a 33 ppm sulfur gasoline, NOx emissions for each phase of the test cycle, including the cold-start portion of the test increased with each subsequent FTP test run with the vehicle (a total of three FTP tests run successively). Cold-start NOx emissions increased from 6.6 g/mi to 8.7 g/mi to 9.2 g/mi over three FTP tests using 33 ppm sulfur gasoline – a 39% increase in NOx cold-start emissions for the third FTP test compared to the first FTP test. The use of secondary air and low thermal mass substrates did not make this vehicle insensitive to cold-start sulfur poisoning. In this case sulfur is accumulating on the available active catalyst surfaces and negatively impacting the catalysts' cold-start NOx performance (and the catalysts' NOx performance in the other two phases of the test cycle). Triplicate FTP tests run on this same PZEV vehicle using a 3 ppm sulfur gasoline did not show any negative NOx emission trends in the cold-start phase or any other phase of the test cycle. The negative impacts of sulfur on NOx performance observed with the 33 ppm sulfur gasoline were also largely erased by running higher speed US06 test cycles between each FTP test. In this case, the higher speed operation of the vehicle between FTP testing creates higher catalyst temperatures that can purge sulfur that accumulates on the active catalysts during the cooler FTP test cycle.

MECA is unaware of any cold-start emission control technology that is not impacted by fuel sulfur levels since ultimately the cold-start emission performance is tied to the precious metal-containing three-way catalyst performance. API's and AFPM's premise that cold-start emissions can be zeroed out by a sulfur insensitive technology has no basis in fact. As indicated in our earlier comments, MECA agrees with EPA's assessment that a critically important element to ensuring that future gasoline vehicles will be able to comply with EPA's proposed Tier 3 emission limits is EPA's proposed reduction of gasoline fuel sulfur levels to a 10 ppm national average starting in 2017. 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 public website, www.meca.org, under Resources >> Reports). This MECA gasoline fuel sulfur report includes the Toyota 2000 SAE paper reference that showed strong sulfur sensitivity on the emissions performance of a prototype SULEV vehicle that employed a close-coupled three-way catalyst and an underfloor converter that utilized a combination three-way catalyst plus hydrocarbon adsorber design. In their published test results both hydrocarbon and NOx FTP emissions increased significantly when the gasoline fuel sulfur level was increased from 8 ppm to 33 ppm (additional large increases in hydrocarbon and NOx FTP emissions were observed when the fuel sulfur level was increased to 150 ppm). The reference for this Toyota paper is SAE paper number 2000-01-2019. API and AFPM note in

their comments that EPA neglected to include a reference for this work in their Tier 3 proposal.

API and AFPM in their Tier 3 comments are also negative concerning the future application of lean burn, gasoline direct injection engine technology in the U.S. to comply with future EPA greenhouse gas/fuel economy standards. Their comments indicate that the market share for lean-burn engines in the U.S. will reach only about 3% between 2015 and 2020 and decline thereafter (based on research done by The Martec Group). The auto industry has generally expressed significant interest in lean GDI engines in comments made at both Tier 3 public hearings held in Philadelphia and Chicago in April 2013. This auto industry interest is specific to the potential for lean GDI engines to deliver up to 20% improvements in fuel consumption relative to stoichiometric GDI engines (which in turn have lower fuel consumption than port fuel injection gasoline engines). A recent analysis of EPA's estimates of costs to meet their future light-duty 2017-2025 greenhouse gas emission standards by Dr. Timothy Johnson of Corning, Inc. (see *SAE Int. J. Engines* 6(2):2013, doi:10.4271/2013-01-0538) indicates that CO₂ reductions will cost about \$100/% CO₂ reduced in the 2020-2025 timeframe. According to recent Ricardo estimates, lean GDI engine technology can deliver about 20% lower fuel consumption at a cost of about \$30/% CO₂ reduced. This relatively attractive cost for reducing CO₂ emissions relative to EPA's estimates for costs to reduce CO₂ emissions in the 2020-2025 timeframe should drive auto industry interest and adoption of lean GDI engines to meet future U.S. greenhouse gas standards.

As MECA and the auto industry have both pointed out in public comments, a 10 ppm sulfur average gasoline standard is an important enabler for allowing lean GDI engines to meet proposed Tier 3 emission limits and deliver cost effective CO₂ reductions. In our previous Tier 3 comments, MECA noted that lean NO_x adsorber catalysts are the preferred strategy for reducing NO_x on lean GDI light-duty engines and NO_x adsorber catalysts have known strong sensitivities to gasoline fuel sulfur levels (see for example Toyota's SAE paper number 2000-01-2019 referred to previously). At least two European auto manufacturers offer lean GDI vehicles that utilize lean NO_x adsorber catalysts for NO_x control in Europe and the current gasoline sulfur levels present in the U.S. market prevent these manufacturers from offering these lean GDI vehicles in the U.S. market. Emission control manufacturers are working with their automotive customers to make lean NO_x adsorber catalysts more effective and less costly (as shown in the recent SAE paper number 2013-01-1299, referenced in MECA's earlier Tier 3 comments), but lower sulfur gasoline is necessary to make lean GDI a viable future option in the U.S. market. Without 10 ppm sulfur gasoline, manufacturers will be forced to use more costly approaches for reducing CO₂ emissions from future light-duty vehicles.

On the issue of Tier 3 compliance costs, MECA has reviewed comments submitted by the International Council on Clean Transportation (ICCT, Tier 3 comments dated July 1, 2013) on this issue. ICCT points out numerous recent published references that have allowed auto manufacturers to reduce precious metal content of three-way catalysts to meet current Tier 2/LEV II and future LEV III/proposed Tier 3 emission standards by utilizing catalyst technology improvements that catalyst manufacturers have introduced over the past six to seven years. MECA believes that a number of factors will allow projected Tier 3 compliance costs to be lower than EPA estimates contained in their Tier 3 Draft Regulatory Impact Analysis. These factors include available and continued improvements in three-way catalyst technology, the additional

flexibility of meeting a combined NMOG+NO_x Tier 3 standard versus meeting individual NMOG and NO_x emission standards (see for example SAE paper number 2012-01-1245 authored by Ball and Moser), and the trend of engine/vehicle downsizing that auto manufacturers will use to comply with EPA's future fuel economy/greenhouse gas emission standards. All three of these factors should help to drive costs out of future emission systems designed for Tier 3 applications. A factor that may drive future Tier 3 precious metal catalyst loadings higher is the expected cooler exhaust temperatures that will be available from light-duty vehicles as auto manufacturers move to more efficient powertrains in response to EPA's future light-duty fuel efficiency/greenhouse gas standards. On balance, MECA agrees with ICCT's analysis that Tier 3 compliance costs are likely to be lower than the EPA estimates provided in their Tier 3 proposal.

Finally, MECA would like to reiterate our strong support for EPA harmonizing with ARB's LEV III 1 mg/mile FTP PM standard. In July 2013 MECA released a new report on ultrafine particulate (UFP) emissions entitled, "Ultrafine Particulate Matter and the Benefits of Reducing Particle Numbers in the United States." The report summarizes the current understanding of the potential adverse health impacts of UFPs; outlines the various control strategies and technologies that can be used to meet current and upcoming U.S. EPA and California ARB emission standards (including LEV III and EPA's proposed Tier 3 standards); and documents the success story of using diesel particulate filters (DPFs) to meet and exceed U.S. and European emission standards. Notably, the report highlights a correlation between particle number (PN) and PM that can be used in conjunction with PM-based health data to estimate the health benefits of reducing particle number emissions, and indicates that a PN measurement may offer a more robust unit for determining compliance at very low PM mass levels. In addition, the report quantifies the health benefits of the additional emission reductions that are realized when DPFs or gasoline particulate filters (GPFs) are used compared to only engine-based strategies. With respect to light-duty vehicles, the report echoes many of the comments made by MECA with respect to the expected dominant use of GDI engines in the U.S. because of their improved fuel economy versus port injected gasoline engines, the higher particle mass and number emissions of GDI engines relative to port injected engines, and the recommendation that EPA follow California's lead in including a 1 mg/mile PM FTP limit in its final Tier 3 standards. Gasoline particulate filters are a cost effective emission control technology option for meeting a 1 mg/mile FTP PM standard, and GPFs are expected to be introduced in Europe in the near future on some GDI models to meet the Euro 6 GDI PN limit of 6×10^{11} particles/km. As discussed in this report, compliance at the 1 mg/mile PM level provides significant additional health benefits beyond the benefits included by EPA in their Tier 3 proposal. The full MECA report on ultrafine particulates is available on MECA's public website, www.meca.org, under Resources >> Reports. It is important for 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. EPA 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.

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 EPA's proposed Tier 3 program. 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. MECA strongly supports EPA's Tier 3 emissions and fuel standards proposal, believes that Tier 3 compliance costs will be lower than the EPA estimates contained in their Tier 3 proposal, asks EPA to harmonize with ARB's 1 mg/mile FTP PM standard, and urges EPA to finalize these proposals by the end of this year.

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