COMMENTS OF THE MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION ON CALIFORNIA AIR RESOURCES BOARD'S ADVANCED CLEAN CARS MIDTERM REVIEW

March 20, 2017

The Manufacturers of Emission Controls Association (MECA) is pleased to provide comments on the California Air Resources Board (ARB) Advanced Clean Cars Midterm Review: Summary Report for the Technical Analysis of the Light Duty Vehicle Standards that examines the ZEV regulation, the 1 milligram per mile (mg/mi) particulate matter (PM) emission standard, and a general review of the format of the greenhouse gas (GHG) standards. The report includes a wide range of information on technologies and issues relevant to GHG and PM emissions for MY2022-2025. We found this review to be thorough and comprehensive in its presentation of issues concerning California's Advanced Clean Cars Program. In addition, this information nicely complements the Midterm Evaluation conducted by USEPA based on the draft Technology Assessment Report written together with NHTSA and ARB. MECA supports staff's conclusions, and we will focus comments on the topics of meeting the 2022-2025 GHG standards, PM and black carbon emissions and technologies to meet the 1 mg/mi PM standard, off-cycle credits, and evaporative emission concerns from PHEVs.

MECA is a non-profit association of the world's leading manufacturers of emission control, combustion efficiency and GHG reduction technology for mobile sources. Our members have over 40 years of experience and a proven track record in developing and manufacturing technologies for reducing criteria emissions and improving engine efficiency for a wide variety of on-road and off-road vehicles and equipment, including extensive experience in developing GHG reducing 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 to mitigate air quality problems and minimize the impacts of climate change.

We find that ARB's staff report clearly presents the significant advances that have been made by technology providers and vehicle manufacturers to achieve significant improvements in fuel efficiency and very low PM emission levels from light-duty vehicles. It is clear that the pace of efficiency technology introduction and the breadth of technology options available for compliance has grown beyond early projections. At this point of the implementation of the standards, MECA members continue to believe that an important opportunity remains to significantly reduce greenhouse gas emissions and improve fuel economy from passenger cars, light-duty trucks, and medium-duty passenger vehicles. We support the conclusions of EPA's Midterm Evaluation and Proposed Determination as well as ARB's staff report that the majority of the GHG reductions and efficiency improvements out to 2025 are still achievable through the broader deployment of efficiency technologies in conventional internal combustion powertrains and vehicles. MECA would like to reference our comments to the EPA Midterm Evaluation of the national LDV GHG standards (see: MECA comments to Federal Docket ID EPA–HQ–OAR–2015–0827).

Controlling greenhouse gas emissions from the transportation sector is essential to the overall efforts to alleviate long-term impacts on the climate. As detailed in the multi-agency draft Technical Assessment Report, there is a large set of technology combinations available to reduce greenhouse gas emissions from passenger vehicles and light-duty trucks, including fuel efficient, state-of-the-art and future advanced gasoline and diesel powertrains. The vast majority of technologies being deployed across the light-duty fleet represent components that have existed for decades and are just now being applied to conventional internal combustion diesel and gasoline engines. Once these cost-effective technologies are deployed, suppliers will develop new technologies to continue reducing vehicle CO_2 and GHG emissions to help their customers meet future standards. For the next several decades, there are likely to be numerous cost effective ways to improve fuel economy without extensive use of strong hybridization or full electrification. We continue to support ARB's commitment to meeting California's air quality and climate goals and urge staff to consider an all-of-the-above approach, which relies on performance based policies that facilitate innovation in all areas of vehicle fuel efficiency technologies and refrains from picking technology winners and losers.

Implicit in the federal greenhouse gas emission compliance scenarios is the ability of conventional and advanced powertrain options to meet the applicable criteria pollutant emission standards, such as CO, NOx, and non-methane organic gases (NMOG). In this manner, advanced emission controls for criteria pollutants enable advanced powertrains to also be viable options for reducing greenhouse gas emissions. Future light-duty diesel powertrains will continue to use emission control technologies like diesel particulate filters, NOx adsorber catalysts, and selective catalytic reduction catalysts to meet ARB's light-duty exhaust emission standards. Emission control manufacturers are working with their auto manufacturer partners to further optimize these emission control technologies to be more effective at reducing criteria pollutants and play a role in reducing vehicle greenhouse gas emissions. A recent focus of research has been on cold-start emissions where thermal management strategies and new catalyst formulations are being developed to activate catalyst functionality at lower temperatures, earlier in the warm-up cycle. The ability to control NOx over a broader temperature range offers the calibration engineers with a wider operating window for calibrating the engine for greater fuel efficiency and thus lower GHG emissions. Advanced diesel emission control technologies like particulate filters with lower backpressure characteristics, SCR catalysts with improved performance at lower exhaust temperatures, and SCR catalyst coated directly on particulate filter substrates are examples of emerging diesel emission control technologies that will allow future diesel powertrains to be as clean as gasoline engines while retaining the improved fuel consumption characteristics of compression ignition. Coating the SCR directly on the DPF allows the SCR to be moved closer to the turbocharger, thus significantly accelerating heat-up. Several commercial examples of SCR coated filters installed on light-duty vehicles already exist in Europe, and we expect this number to continue to grow.

Another aspect of the research to optimize vehicles for cold-start emissions performance will benefit hybrid electric vehicles (HEVs) and plug-in hybrids (PHEVs), which are forecast to be an increasing share of the population of new vehicles in the future and are projected to play an important role in California. One of the primary strategies employed by HEVs and PHEVs to reduce tailpipe emissions is to shut off the internal combustion engine and run the vehicle off of the battery. This practice can result in multiple engine stop-starts in each vehicle trip. Emission control manufacturers are working on improved low-temperature catalysts that will effectively reduce criteria pollutants from vehicles that operate with colder exhaust temperatures for longer durations. To complement these improved catalysts, thermal management strategies are being tailored to HEVs and PHEVs in order to retain the heat in the exhaust emission control systems, which will allow the catalysts to operate at high efficiency when the engine restarts after a period of battery-only operation.

Since the original rule was proposed, a new category of catalysts has emerged for both diesel and gasoline applications, specifically targeting cold-start and low temperature emissions. These catalysts are generically referred to as passive NOx adsorbers (PNAs). This family of catalysts serves to physically adsorb NOx at low temperatures, from the time of first ignition, until the active NOx conversion catalyst reaches the light-off temperature. Above temperatures of approximately 200˚C, the NOx adsorber passively releases the NOx so it can be chemically converted to nitrogen by the three-way catalyst (TWC) or SCR catalyst downstream in the tailpipe. In gasoline applications, the PNA can be combined with a hydrocarbon adsorption functionality to help vehicle manufacturers achieve the tighter LEV III/Tier 3 NMHC+NOx limits. In diesel applications, the PNA can be combined with the oxidation functionality of the diesel oxidation catalyst (DOC) to achieve low HC and CO emissions and the proper concentration of NO_2 for the SCR. The PNA is just one example of how cold-start technologies can be used for more fuel-efficient engine calibration. To deploy both conventional and advanced catalysts, substrate manufacturers have developed high porosity flow-through and filter substrate materials with high cell densities to allow higher catalyst loadings and lower back pressures. The higher geometric surface area of these high cell density substrates provides the OEMs with flexibility to design system architectures for improved activity or smaller size. Both the size and back pressure of emission control devices can be used to improve the fuel economy of the vehicle.

Both the TAR and ARB's staff report discuss a range of powertrain technologies, including engine turbochargers, exhaust gas recirculation systems, advanced fuel systems, variable valve actuation technology, advanced transmissions, hybrid powertrain components, and powertrain control modules that can be applied to both light-duty gasoline and diesel powertrains to help improve overall vehicle efficiencies and reduce fuel consumption, both of which can result in lower CO_2 exhaust emissions. Auto manufacturers will take advantage of the synergies between advanced emission control technologies and advanced powertrains to assist in efforts to optimize their performance with respect to both greenhouse gas and criteria pollutant exhaust emissions. MECA believes that light-duty diesel powertrains provide a cost-effective, durable approach for vehicle manufacturers to improve the average fuel economy of their fleets, particularly in the larger power category that includes small pick-up trucks and SUVs. A recent analysis completed by the Martec Group provides an updated cost-benefit analysis for light-duty cars and trucks that details the cost benefits of diesel powertrains as part of a more fuel efficient light-duty fleet (http://www.martecgroup.com/wp-content/uploads/2016/05/The-Martec-Group-White-Paper-Diesel-Engine-Technology-and-the-Midterm-Evaluation-Summer-2016.pdf). We urge the ARB to review the most current diesel cost-benefit information as the Board considers options to meet California's air quality and climate goals.

Manufacturers may choose to deploy lean GDI engines in the future to achieve further efficiencies from gasoline engines. Under lean combustion conditions, similar emission control technologies used on diesel vehicles can be used to reduce emissions from lean, gasoline direct injection powertrains. These include particulate filters to reduce PM emissions and SCR and/or lean NOx adsorber catalysts to reduce NOx emissions. Work at the Oak Ridge National Lab has shown that these lean GDI engines can result in significantly higher PM and PN emissions than even stoichiometric GDI engines. The effectiveness of using a GPF to significantly reduce particulate emissions from a lean GDI engine was published in SAE Technical Paper 2016-01-0937.

MECA commends ARB on its efforts to collect the most recent research and analysis on the zero emission vehicle (ZEV) market. As we noted in previous comments to ARB, MECA advocates for technology neutral, performance-based, emissions standards. In addition, MECA supports the introductory use of incentives to promote innovative technologies that can be disadvantaged by lack of customer exposure and experience. However, in order for a technology to be a sustainable and durable solution, it must demonstrate the ability to compete on the same basis with other technologies to allow consumers the choice that meets their needs and meets performance based standards. EPA recognized this in its light-duty GHG rule by phasing out credits for MY2022-2025 PHEVs, BEVs and FCEVs. These powertrain technologies have been around for decades and have matured to the point where almost every manufacturer is offering multiple models equipped with these technologies, allowing consumers to make informed choices with respect to advanced powertrain vehicles. Furthermore, various federal and state tax credits have been and still are in place to provide consumers incentives for purchasing these vehicles. Another complication with the incentivization of EVs is the uncertainty in the environmental benefits. Numerous studies have shown that in many parts of the country, the temporary 0 gram/mile upstream criteria emissions factor is not seen in the real world due to NOx emissions from electricity generation units that, when operated on combustion sources, exceed the NOx from light-duty vehicles meeting Tier 3 standards. MECA believes that ARB should continue to set performance-based standards and assess whether an existing credit structure creates incentives for technologies that may not be delivering the intended emission reductions over the full well-to-wheels vehicle life cycle in the real world.

In our comments on ARB's original Advanced Clean Cars rulemaking, MECA stressed the need for California to continue to set the bar on light-duty vehicle emission standards, to encourage the development and use of best available control technologies for light-duty vehicles. MECA strongly supported and agreed with ARB's decision to include in their LEV III requirements a 1 mg/mile particulate matter standard for light-duty vehicles over the FTP test cycle. ARB in its midterm review has concluded that it remains appropriate to phase in the 1 mg/mile PM standard beginning in 2025. The reasons cited are that earlier implementation than 2025 model year of the 1 mg/mi PM standard is not supported by ARB's air quality analysis, and the reduced lead time would jeopardize the ability of manufacturers to ensure robust solutions that can be incorporated into scheduled engine redesigns and would likely lead to reliance on more costly, interim solutions such as gasoline particulate filters (GPF) to comply.

MECA would like to provide some information for ARB to consider with respect to these findings. First, the air quality analysis conducted by ARB focused on meeting the National Ambient Air Quality Standard (NAAQS) for PM and the climate benefits of reducing black carbon (BC). The analysis ignored health impacts due to exposure to ultrafine particles ("Ultrafine Particulate Matter and the Benefits of Reducing Particle Numbers in the United States," http://www.meca.org/resources/MECA_UFP_Report_0713_Final.pdf) and unregulated toxic compounds, both of which have been a focus of much of ARB's research funding over the past two decades (In-Vehicle Air Pollution Study, Harbor Communities Monitoring Study, light-duty vehicle PM toxicity study, etc.) and have led the agency to classify diesel PM as a toxic air contaminant. In addition to ultrafine PM from gasoline engines, ARB's own testing determined that black carbon comprises 75% of current gasoline PM, which is most likely due to the prevalence of gasoline direct injection (GDI) vehicles in the modern fleet. This is much higher than the black carbon emitted from traditional port fuel injection (PFI) vehicles. The high black carbon PM emissions from GDI engines is a characteristic that resembles diesel engine PM. MECA suggests that ARB further compare PM emitted from GDI engines to PM emitted from diesel engines without diesel particulate filters (DPF) and analyze the health benefits of reducing GDI PM in this context. A recent study, funded by MECA at the University of California-Riverside CE-CERT labs, characterized the toxic compounds from two GDI vehicles with and without GPFs. Specifically, we looked at polycyclic aromatic hydrocarbons (PAHs), nitro-PAHs and ultrafine metal oxide particles and found that GPFs reduce over 90% of the ultrafine metal particles and over 99% of the solid PAH compounds in the GDI PM. The study also showed that GDI engines can emit high levels of gaseous PAH compounds, and GPFs reduce these by 55-65% from these two vehicles. This work was recently presented at the 2017 CRC MSAT conference in Sacramento. A prior study published by the same authors showed that some GDI vehicles can emit 2-5 times more PAH compounds than conventional PFI vehicles (SAE 16FFL-0362, Baltimore, MD).

Second, MECA questions staff's conclusion that manufacturers need more lead time to bring cost effective 1 mg/mile vehicles to the market. Over the past five years, engine and exhaust control advances have made PM reductions, including tighter particle number standards in Europe starting this year, more cost effective and thus achievable much earlier than 2025. For context, a particle number standard of 6×10^{11} particles per kilometer, which is roughly equivalent to 0.5 mg/mile, has been adopted by the European Union, China and India for implementation in 2017, 2020 and 2023, respectively. The European light-duty GDI particle number limit in conjunction with the adoption of real-world driving emission (RDE) requirements for light-duty vehicles has led European auto manufacturers to introduce cleaner technologies, such as advanced fuel injection systems and/or GPFs, in order to comply with these regulations starting this year. Nearly all auto manufacturers that sell into the European market are working with MECA members on potential applications of GPFs on GDI vehicles. Many of the same US manufacturers that are selling vehicles in California intend to manufacture GPF models for Europe later this year, while European manufacturers that have announced their intention to use GPFs to meet the European particle number limit export similar models to the US with no current plans to include GPFs on US versions of those vehicles.

As ARB's report notes, direct injection technology has been deployed at a rapid pace, enabling gasoline engines to achieve greater fuel efficiency. Although significant advances have also occurred in improving the efficiency of naturally aspirated engines, GDI is expected to continue as the dominant pathway to meeting 2022-2025 light-duty greenhouse gas emission standards. Emissions controls ensure that these more fuel-efficient gasoline engines meet tough

California and federal criteria emission regulations. Under stoichiometric conditions, three-way catalysts are used to achieve ultra-low emissions of NOx, HC and CO. Advanced high performance, three-way catalysts are available and will continue to evolve and be optimized to ensure that future gasoline direct injection engines will meet the toughest criteria pollutant emissions standards with minimal impacts on overall vehicle exhaust system backpressure and fuel consumption.

MECA members in Europe are demonstrating the ability of coating these advanced TWC formulations directly onto GPFs in place of the underfloor TWC converter. This allows GDI engines to comply with the Euro 6c PN requirements starting in September 2017 as well as the more challenging RDE requirements that are being implemented in Europe and other parts of the world in the future. Some vehicle manufacturers are likely to use GPFs to comply with the LEV III, 1 mg/mile PM limit that begins to be phased in 2025. Catalyzed GPFs are being demonstrated in place of today's underfloor catalysts, making this a cost-effective technology for meeting tighter criteria and particulate standards in the future. Numerous papers have shown no measurable impact of GPFs on vehicle fuel economy or CO_2 emissions (Emiss. Control Sci. Technol. DOI 10.1007/s40825-016-0033-3, SAE Technical papers: 2015-01-1073, 2016-01-0941, 2016-01-0925). MECA estimates that the future incremental cost of a catalyzed GPF, above that of an underfloor TWC converter which it replaces, is likely to be in the range of \$50-\$60 in the 2025 time-frame, making GPFs a cost-effective option for complying with the LEV III 1 mg/mile PM standard with no impact on fuel economy. Given the effectiveness of GPFs to reduce particle emissions from GDI engines, MECA believes that ARB should give strong consideration to incentivizing earlier implementation of the 1 mg/mile standard.

ARB committed to develop a more stringent US06 cycle PM emission standard, which would verify PM is well-controlled over more aggressive in-use driving conditions, as well as consider PM emission standards for other test cycles and ambient conditions as necessary to ensure in-use PM emissions are minimized. MECA agrees with ARB's conclusion that tightening the US06 cycle PM emission standard may provide real PM reductions and health benefits. Furthermore, MECA would like to point out a recent demonstration by our sister association in Europe, AECC, that found that real world vehicle particle emissions are higher than emissions measured on test cycles. The study measured GDI vehicles with and without GPFs with RDE cycles on the road and chassis dynamometer. The results indicate that the GDI vehicle without a GPF exceeds the RDE emission limits while the GPF-equipped vehicle's emissions remained well below the limit (see presentation from ECT 2016, http://www.ecmaindia.in/Uploads/image/52imguf_Mr.DirkBosteels(AECC).pdf). In addition, MECA is partnering with South Coast Air Quality Management District on a test program to measure real world PM emissions from light-duty GDI vehicles in Southern California.

ARB acknowledges in its staff report that the black carbon fraction of PM emissions is a recognized short lived climate pollutant with a strong global warming potential (GWP), between 900 and 3200 times more powerful than CO_2, making even small reductions in BC directionally beneficial to meeting California's GHG reduction goals. In addition, ARB's own testing shows that approximately 75% of GDI PM emissions are comprised of BC. MECA suggests that ARB consider offering vehicle manufacturers an incentive for early reduction of BC from GDI vehicles. Such a strategy would provide OEMs with a black carbon-based, CO_2-equivalent credit for going beyond the 3 mg/mile standard prior to 2025, when the 1 mg/mile LEV III PM standard begins to be phased in. ARB's staff report includes examples of the types of technologies, such as GPFs, which can be applied to gasoline vehicles to reduce PM and BC. As previously mentioned, several European vehicle manufacturers have announced broad deployments of GPFs in Europe, starting this year, in order to meet the latest European particle number emission standards, and this same standard has been adopted by China starting in 2020. MECA estimates that a nominal CO_2-equivalent credit of 2 g/mile would offset the cost of a GPF on a GDI vehicle while still enabling the vehicle to meet tight GHG and criteria emission standards, and this may incentivize European vehicle manufacturers to keep the GPF on vehicles exported to the US. The application of best available filtering technology on future gasoline vehicles will provide surplus BC and total PM reductions from this sector and will deliver immediate climate benefits and health co-benefits for the citizens of California. Further detail on this concept is provided in Appendix A attached to the end of this document.

It should be noted that black carbon can have regional climate impacts due to is distribution in the atmosphere and deposition on surfaces in the proximity of its source. Thus, local reductions of BC can result in local climate benefits, which is in contrast to CO_2 due to it being globally mixed. Black carbon particles have high surface area and low mass, so a small mass of black carbon could lead to disproportionately large climate and health impacts. As mass emission standards continue to tighten, ARB should consider alternative metrics (e.g. particle number) to accurately characterize black carbon emissions and their impacts on climate and health. A black carbon credit might also have applicability to other mobile source sectors, such as off-road equipment where the majority of Tier 4 final engines in certain power ranges are certified without DPFs, and as a part of current or future greenhouse gas program.

We commend ARB for recognizing the breadth of engineering ingenuity to reduce real-world CO_2 by including the off-cycle credit program in the Advanced Clean Cars program. US EPA and the European Commission have included an off-cycle CO_2 credit program as part of their light-duty GHG standards. After five years into the U.S. program, the supplier industry has realized that beyond the pre-approved technologies that are included in the off-cycle credit table, the process for credit approval is complex, ill-defined and can stifle early innovation and development at the supplier level before the OEM is prepared to commit the resources necessary to complete a full application. While the current program offers a methodology for OEMs to apply for off-cycle credits, our members' experience has revealed a few shortcomings. Because the program requires that off-cycle technologies be fully integrated into vehicles, suppliers have a difficult time generating enough evidence to convince their customers to commit resources to demonstrate the technology across a fleet of vehicles without any indication of the amount of credits the technology may deliver. Furthermore, suppliers find it difficult to take advantage of the 5-cycle pathway to generating data toward demonstrating the CO_2 reduction benefits of a technology to their customers because they don't have access to the methodology the agency uses for calculating the final credit value.

MECA represents both on-cycle and off-cycle technology suppliers, and therefore we are committed to credit policies that ensure measurable and verifiable CO_2 emission reductions in the real-world. We do believe that once the currently approved off-cycle technologies are deployed, it will become necessary to incentivize new cost effective technologies in order to meet the goals of this regulation beyond 2025. We believe that ARB should consider including a quantifiable and verifiable off-cycle CO_2 credit program, for which suppliers can qualify and submit applications, as part of future vehicle GHG regulations to be implemented in the post 2025 timeframe. There are several policy examples where certification flexibilities have been used to incentivize early market introduction of advanced technologies. For example the Eco-innovation program that is part of the European Commission's light-duty GHG standards provides a pathway for both technology suppliers and vehicle manufacturers to demonstrate and apply for off-cycle technologies (https://circabc.europa.eu/sd/a/bbf05038-a907-4298-83ee-3d6cce3b4231/Technical%20Guidelines%20October%202015.pdf). Furthermore, examples of regulatory policies that offer a step-wise process towards full certification exist for both diesel retrofits through ARB's conditional verification program and new certification of engines or hybrid powertrains as proposed under ARB's Innovative Technologies Regulation. Such a step-wise approach allows for an initial demonstration and conditional pre-approval of a technology's emission reduction potential prior to completing the full certification process. In addition, this type of approach offers manufacturers a pathway to manage uncertainty during the resource-intensive processes of full certification and compliance.

For the case of certifying technologies for off-cycle credits, this could begin with initial demonstration of the technology on a limited number of vehicles, combined with fleet simulation data across broader vehicle categories and real-world conditions under which the technology may offer CO_2 reductions. After review of the preliminary data, ARB could assign a conservative and conditional pre-approved credit value to a technology that the supplier could use to get its OEM customers interested in allocating the resources to complete the full off-cycle credit application. Once introduced into the market, a more accurate and statistically sound assessment of the CO_2 reduction benefits of the technology can be demonstrated following the first year of real-world, market deployment across the manufacturer's fleet. Following a review of the field results, the final credit allocation could be adjusted appropriately based on real-world experience. The OBD system that records the fuel consumption of a vehicle may be a way to obtain a statistical representation of the real-world off-cycle credit value. MECA and our members would like to work with ARB staff to develop a clearly defined, rigorous approach that involves the technology supplier as well as the vehicle manufacturer in the application process through a step-wise pathway that manages the risk of complete certification. Such an approach would also allow the ARB, the suppliers and the vehicle manufacturers to best manage their resources. Further resource sharing across broader agency experience could be accomplished by expanding the off-cycle credit process to include all three agencies (ARB, EPA, NHTSA) in reviewing data and assigning credits to off-cycle technology pathways.

Both EPA's Midterm Evaluation and ARB's Advanced Clean Cars Midterm Review point to an eventual growth in the use of PHEVs as part of the overall fleet compliance strategy beyond 2025. EPA predicts modest increases beyond 2021, but IHS Markit and others project more significant increases in the future. Most PHEVs employ fuel system designs which seal the fuel tank, allowing it to build modest pressure (up to 35 kPa) under real world operating conditions, as a strategy to eliminate fuel tank venting-related hot soak and diurnal emissions. The purpose for sealing the tank is that the vehicle can operate for extended driving/parking cycles on charge depleting mode without operation of the ICE and the accompanying purge needed to regenerate the carbon canister. Sealing the fuel tank during parking and hot soak prevents vapors from venting to the canister and enables the vehicle to meet certification requirements without forcing purge during this charge depleting operation. Depending on system design and calibrations, the tank may vent running loss emissions to the engine, but the tank is sealed when the key is off, except for refueling. Fuel tanks operating under higher pressures will, in some operating conditions, vent VOC to the atmosphere upon cap removal at the time of refueling. This is commonly referred to as "puff losses." A second unintended consequence resulting from a transition to hybrid vehicles with sealed tanks centers around the newly adopted fuel/evaporative control system leak standard for 2018 and later model years recently established as part of the LEVIII/Tier 3 light-duty criteria pollutant standards. This standard prohibits any fuel/evaporative system orifices in excess of a cumulative diameter of 0.020 inch. However, data show that any leak size >0.002 inch in a sealed system will generate emissions higher than an open system with 0.02 inch leak orifice, vented through the canister. ARB should take the earliest opportunity to incorporate provisions in the evaporative test procedures to address these emissions sources and prevent backsliding in the VOC inventory related to new technology that will be implemented as a consequence of the light-duty GHG rule. Please refer to Appendix B for more detail on evaporative emissions issues related to sealed fuel tanks.

In summary, significant opportunities remain to further reduce greenhouse gas emissions from the transportation sector through the design of powertrains that include advanced exhaust emission controls along with advanced efficiency components for meeting the LEV III emission standards, as well as the 2022-2025 GHG requirements. MECA believes that advanced efficiency and emission control systems have a critically important role in future policies that aim to reduce both mobile source criteria and greenhouse gas emissions. MECA members are developing the technologies that will allow advanced fuel-efficient powertrain designs to incorporate appropriate emission controls, in order to optimize the overall fuel consumption of the vehicle while achieving the tightest criteria pollutant standards in the world. This optimization extends beyond carbon dioxide emissions to include other significant greenhouse gases and climate forcing pollutants such as methane, nitrous oxide, and black carbon. MECA commends ARB staff for a thorough review and analysis of the technological progress that has been made in advanced light-duty powertrains and vehicle efficiency since the rule was proposed in 2012. Because the rest of the world is moving ahead with tighter particulate standards than 1 mg/mile based on particle number limits, MECA suggests ARB consider a strategy to incentivize these same best available control technologies in California through early compliance with the 1 mg/mile PM standard. Such a strategy has the potential to result in significant immediate climate and health benefits to the citizens of California. To help suppliers bring off-cycle technologies to market, MECA would like to work with ARB to develop a phased-in certification process, like the Innovative Technologies Regulation, that is open to both suppliers and vehicle manufacturers and able to give an initial conditional estimated off-cycle credit value, which could be adjusted as part of the final OEM application based on real-world, OBD verifiable fleet demonstration. Finally, we urge the agency to consider the interactions between GHG and criteria pollutant emissions as part of future regulations to avoid unintended consequences that may be caused by conflicting requirements under independent rules. We foresee such a possible scenario with evaporative emissions from PHEVs as detailed in our comments. Our industry will continue to do our part to deliver cost-effective, advanced efficiency, GHG reduction and emission control technologies to allow California to meet its climate and clean air goals.

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APPENDIX A

March 20, 2017

Proposed Voluntary CO_2 Credit for Installing GPFs on Gasoline Cars

Problem Statement

- GDI's emit higher levels of fine particulates (PN, particles/mi) than PFI gasoline cars.
  - Recent studies show higher PAH emissions from GDI than from PFI engines [1,2,3]. GPFs drop PAH emissions by over 90%, indicating PAHs are closely tied to PM [2,4].
  - Hot starts also result in high PN emissions for both GDI and PFI cars[5], and problematic for HEVs [6,7].
  - Injector deposit formation causes higher particulate emissions as the engine ages, and are difficult to avoid [8,9].
- European and Chinese cars (2017 and 2020, respectively) will widely use gasoline particulate filters to dramatically reduce PN emissions. But GPFs will not be widely used in the US, as the Tier 3/LEVIII PM regulations can be met without them.
- It is quite likely in-use testing of vehicles will increase in the future, showing high in-use PN emissions. This will raise questions by the public on why GPFs are not used in the US.
- The black carbon particulate emissions of MY 2010-11 GDI and PFI engines on the hot parts of the FTP are about 2-3 mg/mi, and are 90% removed by GPF [10]. Cold start emissions are much higher.
  - These emissions will represent about 1.3 to 2.6% of the equivalent carbon dioxide footprint (GWP=2000) of the average US passenger car fleet in 2025.
  - Modern engines emit on the order of 1-2 mg/mi black carbon, representing 1.25 to 2.5% CO_2 (eq.) in 2025.
  - At an approximate efficiency technology cost to OEMs of $70-100/% CO_2 reduction in 2025 [11], the black carbon has a nominal $160 equivalent CO_2 reduction value.
  - However, OEMs have no capability to recover this value if they reduce their PM emissions early.

Proposal

- Allow the OEMs a voluntary 2 g/mi CO_2 credit (1 mg/mi BC or ~1.25% CO_2 in 2025) for installing a high-efficiency GPF (>80% PM reduction) on their gasoline engines early and reduce PM/BC below 3 mg/mile ahead of the 1 mg/mile standard in 2025.

Benefit

- The 2 g/mi CO_2 credit will incentivize GPFs by covering the cost ($50-$60, incremental to a TWC in 2025). OEMs will install more GPFs than otherwise.
- Significant public health benefits will result. The GPF will reduce PM, PN, and PAH emissions to near-zero levels, and provide these benefits in-use and over the life of the vehicle [12].
- Black carbon is a short-lived climate pollutant, resulting in near-term reductions in California.
- The 2 g/mi CO_2 credit is very conservative, resulting in 2X more CO_2 (eq.) reductions than the credit represents over the life of the vehicle.

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APPENDIX B

March 20, 2017

Both EPA's Midterm Evaluation and ARB's Advanced Clean Cars Midterm Review point to an eventual growth in the use of PHEVs as part of the overall fleet compliance strategy beyond 2025.[1,2] EPA predicts modest increases beyond 2021, but IHS Markit and others project more significant increases in the future.[3,4,5] Most PHEVs employ fuel system designs which place the fuel tank under pressure (up to 35 kPa) as a strategy to eliminate fuel tank venting-related hot soak and diurnal emissions. The purpose for sealing the tank is that the vehicle can operate for extended driving/parking cycles on charge depleting mode without operation of the ICE and the accompanying purge. Sealing the fuel tank during parking and hot soak prevents vapors from venting to the canister and enables the vehicle to meet certification requirements without forcing purge during this charge depleting operation. Depending on system design and calibrations, the tank may vent running loss emissions to the engine, but the tank is sealed when the key is off, except for refueling. Fuel tanks operating under higher pressures will, in some operating conditions, vent VOC to the atmosphere upon cap removal at the time of refueling. This is commonly referred to as "puff losses." EPA and ARB should take the earliest opportunity to incorporate provisions to address this emissions source and prevent backsliding in the VOC inventory related to new technology that will be implemented as a consequence of the light-duty GHG final rule.

Fuel vapor emissions related to pressurized fuel systems have been of concern to ARB and EPA since the early 1990s. Provisions to address these concerns in the ARB and EPA Enhanced Evaporative Emission rules included running loss emission standards, and the regulations also stipulated that: 1) all fuel tank vapor must be vented to the canister and 2) that fuel tank pressures during the running loss test may not exceed 10 inches water (2.5 kPa) unless the fuel tank is vented to the canister upon cap removal.[6] The second of these provisions was promulgated without a test procedure or emission standard. Even though approaches were discussed to incorporate cap removal emissions into the hot soak test following the running loss test and further study and potential action was indicated in the Enhanced Evaporative and ORVR rulemakings, no provisions have yet been adopted.[7]

Once manufacturers began to express interest in PHEVs, the fuel system designs began to incorporate a new evaporative control system configuration known as a non-integrated refueling canister only system (NIRCOS). A NIRCOS is a vehicle in which the canister is used solely for control of refueling emissions[8], and diurnal and hot soak emissions are controlled by sealing the tank. In response to these new designs, in 2009 ARB promulgated new evaporative and refueling test procedures for vehicles with NIRCOS.[9] Among other changes, paragraph 3.3.6.6 of these California test procedures required cap removal in the SHED following the preconditioning and soak steps before the certification refueling test. Fuel tank temperatures following the soak are about 26.7°C. While this provision was a step in the right direction, it likely results in zero cap removal emissions being vented to the canister (in fact, the tank will typically be under a slight vacuum) before the refueling test because of the preconditioning steps and fuel temperatures in the test procedures. These conditions are not representative of most in-use conditions where tank pressures are typically positive.

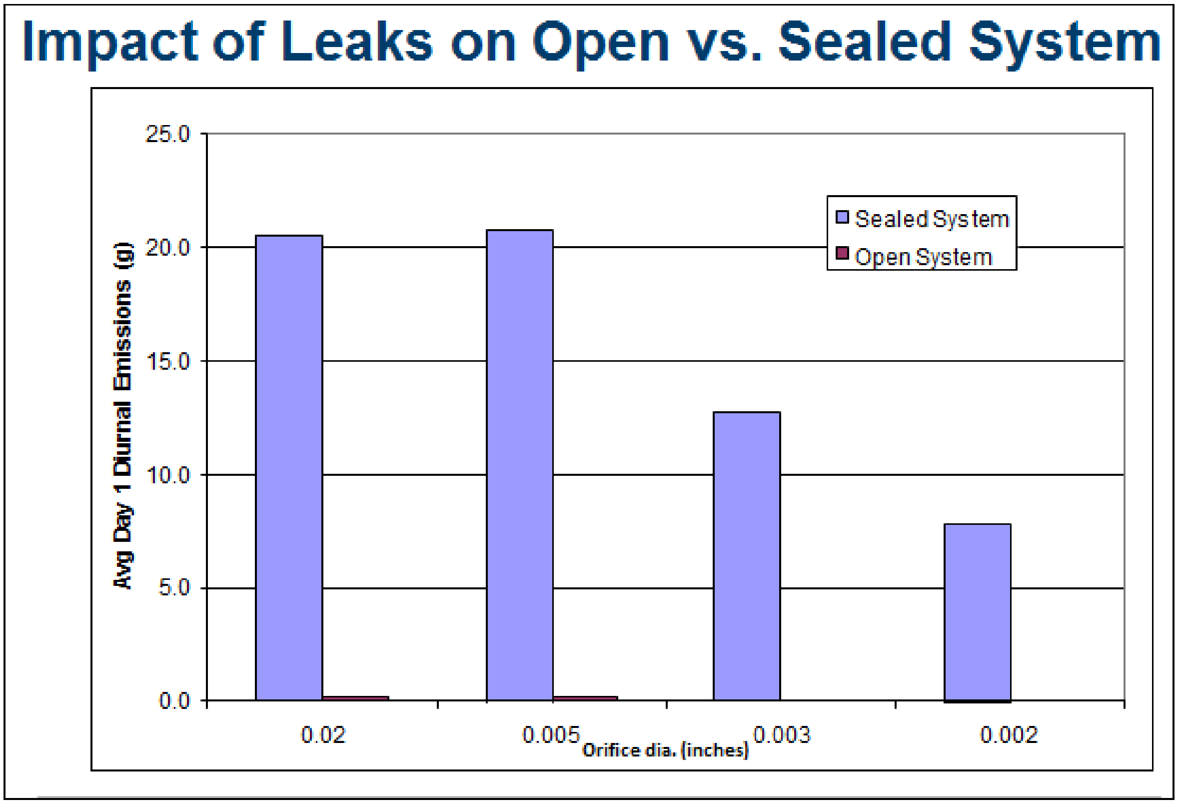
Provisions in paragraphs 8.1.10 and 8.2.5 were stronger. They specified: "Tank pressure shall not exceed 10 inches of water during the running loss test unless a pressurized system is used and the manufacturer demonstrates in a separate test that vapor would not be vented to the atmosphere if the fuel fill pipe cap was removed at the end of the test. For 2012 and subsequent model-year off-vehicle charge capable hybrid electric vehicles that are equipped with non-integrated refueling canister-only systems, a manufacturer shall demonstrate in either a separate test or an engineering evaluation, that vapor would not be vented to the atmosphere if the fuel fill pipe cap was removed at the end of the test." This provision lacked a test procedure and emission standard. Although EPA and ARB have recognized the need to control fuel cap removal emissions from vehicles with higher tank pressures such as PHEVs, neither has adopted appropriate test procedures or an emission standard.

MECA members have modeled the level of puff emissions that may be expected in real-world operation. There are two major operating factors that affect the magnitude of puff losses. The fuel tank temperature at the time of cap removal and the amount of air in the fuel tank at refueling. Generally, as fuel tank temperatures increase, the puff losses increase. While the current California refueling procedures require a tank temperature of 26.7°C at the time of cap removal, this is by far not the worst case condition. In many parts of the country, including southern California, tank temperatures can easily reach 46-53°C following the running loss drive. This was documented in EPA's 2014 tank temperature evaluation.[10] The amount of air in the fuel tank at the time of refueling is also an important factor to puff emissions. Most NIRCOS tanks operate with a vacuum relief valve during parking conditions and can be vented to the atmosphere during driving. Ultimately, the amount of air vented is dependent upon the soak temperature prior to the running loss drive or whether the tank is vented during the running loss drive. Under running loss driving conditions, modeling shows that puff losses can reach 35-50 grams per refueling event. These emissions are half to two-thirds the level of uncontrolled refueling emissions. The issue is that the puff losses always occur prior to a refueling event, and during in-use conditions the canister can be preloaded with 35-50 grams of vapor before the canister functions to control the approximately 75 grams of refueling vapor during ORVR. In-use, the canister needs approximately 110-125 grams of capacity for full control of the puff and refueling event. On the other hand, during certification the canister is not preloaded with puff losses, so the canister only needs to control the approximately 75 grams of displaced refueling vapor. The certification conditions result in a technology package response of capacity only needed for controlling the 75 grams of refueling vapor and no puff losses.

These modeling estimates were corroborated in bench testing of the NIRCOS fuel system from a commercially available PHEV. The fuel system was drained to 10% fill, soaked at 22°C, and then heated to 52°C over 66 minutes to simulate running loss driving conditions. The tank reached a pressure of 31.5 kPa and was venting to the canister at this pressure. The tank pressure was then relieved, and the tank vented a total of 53 grams of vapor during the heat build and puff. The fuel tank was subsequently filled with 21°C, 62 kPa gasoline, and emissions from the canister were 16 grams. Refueling control efficiency (i.e., ORVR) was only 47%. Under certification conditions, this vehicle achieved better than 95% control efficiency. The difference was due to the 53 grams of puff losses loaded onto the canister following running loss driving conditions. While cap removal (puff) emissions are not in the evaporative emissions inventory today as they may be small for vehicles with non-sealed fuel tanks, they are a significant concern as the light-duty fleet transitions to a hybridized or PHEV fleet with higher fuel tank operating pressures and NIRCOS evaporative control systems as a result of tighter GHG regulations. An increase in PHEV sales related to the 2022 and later model year GHG and fuel economy rules would lead to an unintended increase in the VOC inventory. This potential increase can be remedied with appropriate test procedures and emission standards for vehicles with higher fuel tank pressures.

A second unintended consequence resulting from a transition to hybrid vehicles with sealed tanks centers around the newly adopted fuel/evaporative control system leak standard for 2018 and later model years recently established as part of the Tier 3 light-duty criteria pollutant standards. This standard prohibits any fuel/evaporative system orifices in excess of a cumulative diameter of 0.020 inch. The final rule recognized that systems with higher tank pressures would bleed emissions to the atmosphere more rapidly than those operating near atmospheric pressure. EPA deferred action on new measures to address smaller leaks from these pressurized systems pending further evaluation and coordination with ARB.[12]

Data provided to EPA in the comments to the 2013 Tier 3 NPRM (see EPA-HQ-OAR-2011-0135-04370) and discussed in meetings with ARB staff in El Monte and Sacramento in July 2016 (also presented graphically below), show that any leak size >0.002 inch in a sealed system will generate emissions higher than an open system with 0.02 inch leak orifice, vented through the canister. Evaporative control system leaks of greater than 0.020 inch cumulative diameter are found on about 3 percent of vehicles.[13] OBD requirements currently tolerate leaks less than 0.020 inch, but the frequency of these allowed leaks is unknown. It can be assumed that the frequency of these allowed leaks exceeds the frequency of those exceeding the 0.020-inch threshold. One can see from the figure below that if leaks smaller than 0.020 inch occur on vehicles such as PHEVs with sealed fuel systems, the impact on the mass emission rate is significant. Emissions are totally uncontrolled on sealed systems when the leak exceeds 0.005 inch. With the expected increase in vehicles with higher tank pressures such as NIRCOS equipped PHEVs, the in-use VOC emissions related to leaks would be expected to increase and the recently adopted EPA and ARB leak standard would not control these emissions. ARB and EPA should propose a more stringent OBD evaporative system leak detection threshold and leak standard for vehicles with sealed fuel systems. The potential impacts to VOC emissions from future vehicle advances that are likely to result from tighter GHG standards highlights the need to develop holistic emission standards beyond 2025 that harmonize all emissions from vehicles under one regulation and promote the optimization of GHG and criteria reductions in parallel.



[1] See US Federal Register, 77FR62652, October 15, 2012.

[2] See https://www3.epa.gov/otaq/climate/mte.htm, last accessed August 30, 2016.

[3] IHS Markit, "US Powertrain Evolution on the Approach to CAFE 2025", Andrew Wrobel, Senior Analyst, September, 2016.

[4] "PHEV Marketplace Penetration - An Agent Based Simulation", UMTRI 2009-32, July, 2009.

[5] "Plug-in Hybrid Electric Vehicle Market Penetration Scenarios," Department of Energy, PNNL 17441.

[6] See US Federal Register, 58 FR 16001, March 24, 1993. Note especially §89.098-08 and §86.134-96 and California Evaporative Emission Standards and Test Procedures for 1978-2000 Model Motor Vehicles, 4(f)(2) and 4(g)(viii)(A)(X).

[7] See US Federal Register, 58 FR 16012, March 24, 1993 and 59 FR 16272, April 6, 1994.

[8] "Non-integrated refueling canister-only system" means a subclass of a non-integrated refueling emission control system, where other non-refueling related evaporative emissions from the vehicle are stored in the fuel tank, instead of in a vapor storage unit(s).

[9] See 13 CCR 1976, "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles, last amended September 2, 2015.

[10] "Fuel Tank Temperature Profile Development for Highway Driving, Final Report," EPA-420-R-14-026, October 2014.

[11] U.S. EPA, "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015," EPA 420R-15-016, Table 5.1, November, 2015.

[12] U.S. EPA, "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Summary and Analysis of Comments, EPA 420R-14-004. pp. 212 and 213, March, 2014.

[13] See US Federal Register, 79 FR 23517, April 28, 2014.