Manufacturers of Emission Controls Association
2101 Wilson Blvd. Suite 530
Arlington, VA 22201
(202) 296-4797

June 9, 2022

**COMMENTS OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE CALIFORNIA AIR RESOURCES BOARD'S PROPOSED
ADVANCED CLEAN CARS II REGULATION**

The Manufacturers of Emission Controls Association (MECA) appreciates the opportunity to provide comments in support of the California Air Resources Board's Proposed Advanced Clean Car II (ACC II) regulations. MECA believes an important opportunity exists until 2035 for LEV and ZEV performance standards to continue to cost effectively reduce NOx, PM, VOCs and GHGs in all segments of the light-duty and medium duty fleets through the application of advanced internal combustion engine and electrified powertrain system technologies. We also support CARB's ZEV assurance measures that will advance ZEV technology and ensure improved durability and operability that will benefit the owners of electric vehicles and contribute to emission reductions.

MECA is a non-profit association of the world's leading manufacturers of technologies for clean mobility. Our members have over 45 years of experience and a proven track record in developing and manufacturing emission control, engine efficiency, battery materials, components and charging as well as electric propulsion technology for a wide variety of on-road and off-road vehicles and equipment in all world markets.

In order to simultaneously meet future NMOG+NOx, PM and GHG emission standards, several pathways are available through a combination of technologies provided by MECA members. These include full electrification as well as electrified powertrains with engines employing advanced combustion components such as turbochargers, EGR systems, cylinder deactivation, exhaust emission control catalysts, substrates and evaporative control system architectures. Our industry has played an important role in the emissions success story associated with light-, medium- and heavy-duty vehicles in the United States, and has continually supported efforts to develop innovative, technology advancing, emission reduction programs to improve ambient and local urban air quality while reducing greenhouse gases.

MECA members represent over 70,000 of the nearly 300,000 North American jobs building the technologies that improve the fuel economy and reduce emissions of today's vehicles. These jobs are located in nearly every state in the United States including California. The mobile source emission control industry has generated hundreds of billions of dollars in U.S. economic activity since 1975 and continues to grow and add more jobs in response to environmental regulations. Emission control, engine efficiency and electric technology manufacturers invest billions of dollars each year in developing the technologies that reduce emissions from mobile sources. In fact, automotive technology suppliers account for approximately 40% of the auto R&D conducted in the U.S. each year[1].

Of particular note, technology suppliers rely upon their legacy businesses to make investments in technology development and manufacturing to prepare for the future needs of their customers. Finalization of the proposed ACC II rule will provide regulatory certainty to suppliers. However, current supply chain disruptions continue to impair vehicle production volumes and supplier profitability. We urge the board and staff to continue to monitor the market and make decisions that will reinforce market stability to obtain the greatest cost-effective criteria pollutant and greenhouse gas reductions.

MECA appreciates the time and effort that CARB staff put into the regulatory process for this important regulation. We thank CARB staff for their dedication in receiving and incorporating feedback from a broad range of stakeholders during the workshops. For your reference, MECA has previously submitted written comments on the October 13, 2021, June 11, 2021, and October 16, 2020 ACC II workshops and we offer these remaining comments to support the finalization of a scientifically based and robust regulatory proposal for light-duty vehicles.

Summary

MECA supports CARB's ACC II with some modifications, which we feel will strengthen the regulation. Our suggestions for CARB's consideration are summarized here and explained in greater detail in the text that follows:

1. CARB should set a tighter PM standard for light-duty vehicles operating on all certification test cycles on par with those in Europe, China and India (approximately 0.5 mg/mile).
2. CARB should set more stringent NMOG+NOx standards for medium-duty vehicles based on best-in-class certification levels.
3. CARB should set tighter PM standards for medium-duty vehicles consistent with existing control technology.
4. CARB should re-evaluate the evaporative canister capacity equation for vehicles with sealed fuel tanks in order to prevent potential backsliding that could result in greater VOC emissions.
5. CARB should allow more flexibility for PHEVs to contribute greater than 20% of a manufacturer's ZEV compliance in the early years of ACC II implementation to provide additional affordable ZEV consumer vehicle choices and as a buffer while charging infrastructure and critical battery material supply chains develop.

ZEV Proposal

MECA member companies continue to invest in batteries, fuel cells and electric powertrains. This includes research and development in critical battery materials and designs, electric motors and battery and electric powertrain management technologies, as well as, their production. It is clear that the investments in technology, announcements of ZEV vehicle introduction and stringent CO_2 targets being set by countries and regions around the world supports the proposed ZEV implementation stringency. MECA members remain concerned about the rate of charging infrastructure build-out as well as short and medium-term availability of sufficient critical minerals to support their investments. In addition, unforeseen disruptions in power availability have occurred. As a result, we ask that the board request scheduled published progress updates on ZEV and infrastructure implementation rates as well as identification of potential challenges to ensure the availability of accurate public information regarding projected ZEV progress in California and the Section 177 states.

Post 2026 PHEV Credit Qualifications

MECA commends CARB on its proposed changes to PHEV minimum requirements. In particular, we support CARB's provision of the transitional credit allowance in 2026-2028 with all-electric range requirement of >30 miles.

PHEVs, as defined by the proposed minimum requirements, will continue to be an important compliance strategy which can integrate and optimize the best of combustion and electric technologies to increase vehicle efficiency and facilitate the transition to fully zero tailpipe emissions vehicles as the charging infrastructure and supply chains develop. In addition, PHEVs have enjoyed particular popularity with subscribers to CARB's Clean Cars 4 All Program.

Table 1. Comparison of Battery Capacities of Conventional, Full Hybrid, Plug-in Hybrid and Battery Electric Vehicles

	2022 Toyota RAV4 AWD 2.5L, 4cyl. 	2022 Toyota RAV4 AWD Hybrid 2.5L, 4cyl. 	2022 Toyota RAV4 Prime AWD PHEV 2.5L, 4cyl. 	2022 Tesla Model Y Long Range AWD BEV 
EPA Fuel Economy (MPGe)	28	40	Elec + Gas: 94 Gas only: 38	Electric 122
Tailpipe & Upstream GHG (grams/mile)	381	267	150 *assumes 69.3% electric only operation	70 **based on Riverside CA electrical grid
CO_2 Avoided (grams/mile) ***with respect to RAV4 AWD conventional gasoline vehicle	-na-	114	231	311
Vehicle Battery Capacity (kWh)	-na-	1.6	18.1	100
Vehicles Produced from 100 kWh battery capacity	-na-	62	5	1
CO_2 Avoided per kWh Battery Capacity (grams/mile)	-na-	71.2	12.8	3.11

Table 1 compares the fuel economy, tailpipe & upstream greenhouse gas emissions and utilized battery capacities of equivalently sized conventional, full hybrid, plug-in hybrid and battery electric vehicles using available data from the EPA/DOE fueleconomy.gov website.

On a vehicle basis, the tailpipe & upstream greenhouse gas emissions of the battery electric vehicle (Tesla Model Y Long Range AWD) would avoid 311 g/mile of CO_2 (ie. $381_{\text{conventional RAV4}} - 70_{\text{Tesla Model Y}} = 311$) compared to avoiding 231 g/mile with the plug-in hybrid (Toyota RAV4 Prime) assuming that only 69.3% of its operation is all-electric. However, on an equivalent battery capacity basis, the last row of Table 1 shows that HEVs and PHEVs use the available battery materials more efficiently than BEVs avoiding considerably higher amounts of CO_2 per kWh of battery capacity. This improved efficiency of hybrids is due to the higher rate of cycling their smaller battery capacities.

With regards to ZEVs, Table 1 shows that deploying 5 PHEVs using the same total battery capacity as one BEV can result in a far greater cumulative amount of avoided CO_2 (5 x 231 g/mile = 155 g/mile of avoided CO_2) while using an equivalent amount of battery materials.

Based on this comparison, we therefore ask that CARB raise the 20% cap that PHEVs can contribute to a manufacturers ZEV obligation in the early years of ACC II. MECA believes that the proposed PHEV minimum requirements address the shortcomings of some earlier generation PHEVs. Allowing a higher PHEV cap in the early years of the ACC II program should serve to stabilize new ZEV vehicle production providing improved consumer access to electrified vehicles and increase the potential for ZEV sales while supply chains and recharging infrastructure are developed. In addition, it has the potential to yield greater greenhouse gas reduction per kWh of available battery capacity.

2026 and Later ZEV Assurance Measures

As the sales of ZEVs increase, it is important to ensure that equivalent consumer protections, as afforded on traditional LDV's, are implemented. MECA believes the assurance and warranty measures as proposed are reasonable.

MECA agrees that a clearly defined battery state of health (SOH) monitor is a critical consumer assurance measure that provides a means for compliance verification of battery and vehicle performance. MECA is supportive of the proposed 80% energy capacity SOH-based minimum warranty of 8 years/100,000 miles for batteries. In addition, CARB may want to consider retaining the current 15 year/150,000 miles warranty as a backstop against premature full battery failures. In addition, CARB should continue to monitor consumer charging (i.e., % fast charging) and V2X behaviors because these conditions have known impacts on battery durability and performance.

MECA encourages CARB's direct involvement in the United Nations Economic Commission for Europe's (UNECE) Working Party on Pollution and Energy (GRPE) efforts on Electric Vehicles and the Environment. This international working group has developed a Global Technical Regulations (GTR) for battery durability and in-use compliance of battery state of health (SOH). This working group is co-chaired by U.S. EPA and the European Commission and CARB's participation offers an opportunity to incorporate CARB's experience in testing and certification of battery electric vehicles into the process for developing harmonized battery durability standards across global regions in order to reduce certification costs and accelerate consumer acceptance and adoption of ZEV technology.

Beyond these initial ZEV assurance measures, we encourage CARB to continue to explore performance standards for ZEV and PHEV vehicles to drive technology innovation for further reductions in their well to wheel emissions. Such metrics could incorporate the per kWh upstream CO_2 emissions, and miles/kWh vehicle in-use consumption. This will ensure a continued focus on further efficiency improvements as opposed to power and acceleration which can drive up the overall CO_2 footprint of electric vehicles.

LEV IV Proposals

At least 60 million light-duty vehicles will be sold prior to 2035 in California and Section 177 states, most of which will remain on the road until 2050. Of these vehicles, at least 16 to 20+ million will be equipped with internal combustion engines. MECA agrees that success will require a parallel approach of increasing EV penetration and tightening LEV emission standards to reduce the environmental impact of transportation. A parallel approach also serves to reinforce environmental justice by affording further protections of frontline communities as well as minimizing the impact of any delays that result from unforeseen market disruptions.

Our analysis of currently available certification data supports that vehicle manufacturers are making substantial progress on the path to the SULEV30 fleet average level with only the inclusion of a modest number of HEVs, PHEVs and BEVs. It has now been over twenty years since the first vehicle was certified to the SULEV30 standard and seven years since the first SULEV20. Advances in catalyst technology and honeycomb substrates have evolved to achieve NMOG+NOx emission levels well below 20 mg/mile and supports CARB's introduction of certification bins below the current lowest level. Furthermore, catalyst coating technology combined with targeted precious metal placement has been successful in controlling costs in light of rising precious metal prices.

The use of existing engine, hybrid powertrains and exhaust emission control architectures have also facilitated achieving the lowest SULEV20 and SULEV30 NMOG+NOx emission levels and significant CO_2 reductions cost-effectively. Today, even larger SUVs and mini-vans with conventional and hybrid powertrains are being certified to the SULEV30 limit while further technology improvements continue to be incorporated into new production vehicles to enable compliance with the declining NMOG+NOx fleet average.

The introduction of the additional bins as proposed by CARB will provide greater certification flexibilities to manufacturers to assist them in meeting tighter fleet average requirements without having to rely on ZEV averaging into their combustion fleet. We also welcome the inclusion of medium-duty passenger vehicles into the combined fleet average along with passenger cars and light-duty trucks as the technologies that our members are commercializing will benefit this entire fleet of vehicles.

MECA fully supports of the following elements of the LEV IV light duty vehicle standards that are defined in the proposed regulation. These include:

- NMOG+NOx fleet average of 30 mg/mile;

- Diminishing levels (50%, 25% and 0%) of ZEVs in 2026, 2027 and 2028 respectively in the NMOG + NOx Fleet Average;
- Removal of higher level certification bins
- The proposed certification bins of SULEV15,20, 25, 30, ULEV40, 50, 60, 70, 125;
- Standalone certification over the FTP, US06 and SC03 certification cycles;
- US06 NMOG+NOx standards equivalent to the FTP standards down to the SULEV30 bin with lower bins remaining at 30 mg/mile;
- Cold start limits at intermediate soak times with three-year phase-in;
- Supplemental cold start with 8 second initial idle with three-year phase-in;
- PHEV high-power cold start NMOG+NOx limit over the US06; and
- Evaporative running loss standard tightened from 0.05 to 0.01 grams/mile;

We are providing additional comments on the LDV FTP and US06 PM limits, the MDV NMOG+NOx and PM limits, MDV in-use compliance, the cap on PHEV ZEV credits, renewable natural gas and hydrogen fueled vehicles and the evaporative emissions minimum canister size limit equation for sealed fuel tank systems. We believe these represent opportunities for further technologically feasible and cost-effective emissions reductions.

LDV FTP and US06 PM Limits

In June 2021, the U.S. EPA announced[2] that it will reconsider the December 2020 decision to retain the particulate matter (PM) National Ambient Air Quality Standards (NAAQS) at 12 $\mu g/m^3$, which were last strengthened in 2012. EPA is reconsidering the December 2020 decision because available scientific evidence and technical information indicate that the current standards may not be adequate to protect public health, as required by the Clean Air Act.

In September 2021, both the United Nations World Health Organization[3] (WHO) and the Health Effects Institute (HEI) concluded that there is no identified safe threshold for $PM_{2.5}$, or black carbon at which no damage to health is observed. In particular, the HEI announced[4] that a recent European study using state-of-the-art exposure methods and large cohorts in high income countries found that health impact risks were still evident at levels lower than current ambient standards for $PM_{2.5}$, NO_2 and O_3. In particular, the study reported that the hazard ratios for natural-cause mortality remained elevated and significant for $PM_{2.5}$ even when the analyses were restricted to observations below 12 $\mu g/m^3$.

University researchers in the U.S. have reported (see Figure 1) that light duty gasoline vehicle emissions remain prominent amongst the emission source sectors that cause the largest absolute disparities for persons of color communities (POCs include Blacks, Hispanics, and Asians)[5].

These latest developments highlight the importance of continued tightening of criteria pollutant standards, and in particular of the $PM_{2.5}$ standards to further reduce exposure and the impacts of the remaining light duty gasoline fueled vehicles on underserved communities.

To meet tightening particulate standards in other global regions, including Europe, China and India, fuel injection and gasoline particulate filter (GPF) suppliers have continued to improve their commercially available technologies. In fact, nearly every European GDI engine car is currently certified with a GPF, and LDVs in Europe have been required to meet the approximate equivalent of a 0.5 mg/mile standard since 2017 due to the implementation of a particle number standard. This standard applies to nearly all driving conditions and cycles. China has gone as far as requiring all diesel and gasoline cars to be equipped with the best available control technology, based on wall flow filters, that diesels have used in the US since 2007.

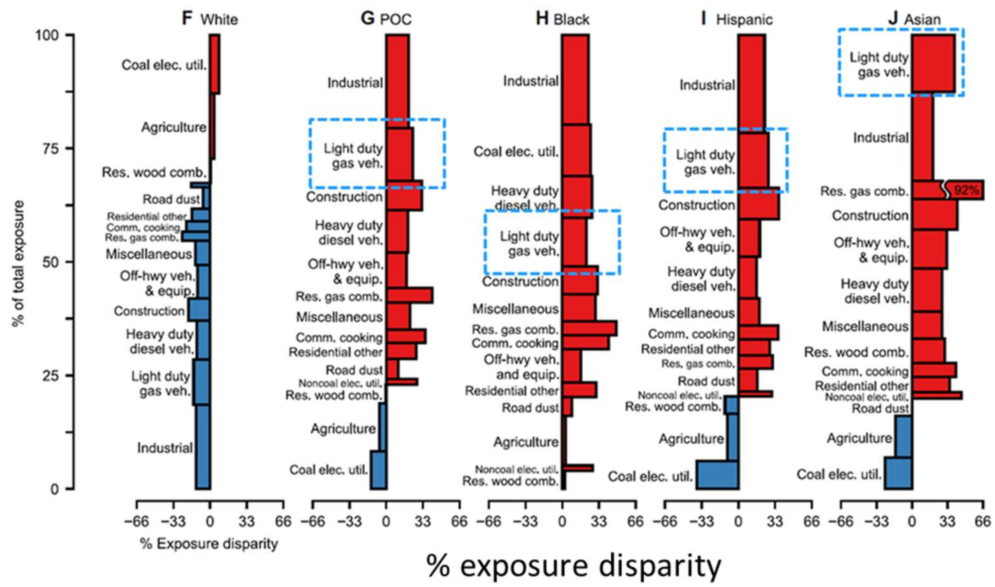

Figure 1. Light duty gasoline vehicles remain prominent amongst the emission source sectors that cause the largest disparities for Persons of Color.

Source: Sci. Adv. 7, eabf4491 (2021) U. Illinois at Urbana-Champaign, U. Washington, UT Austin, UC Berkeley, U. Minnesota

By 2023, before the LEVIII PM limit even begins to phase-in, two-thirds of the major automotive producing regions of the world will be meeting tighter PM emission standards than what CARB has proposed under ACC II. Recent in-use particle mass measurements made from four equivalent vehicle pairs compliant with current U.S. and U.K. standards[6] illustrate the potential particulate mass reductions that could be obtained from adopting equally protective standards as those in Europe, China and India – see Figure 2 below.

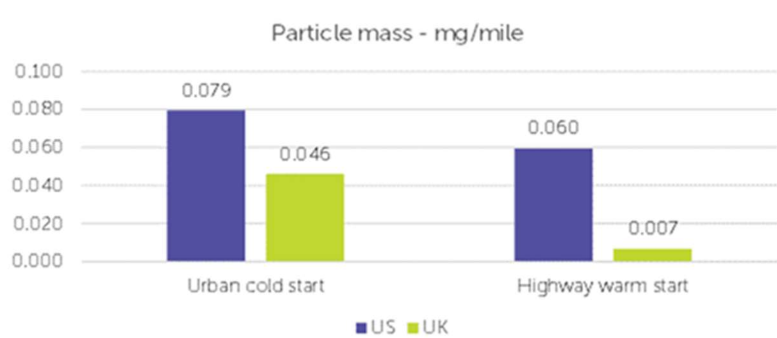

Figure 2. In-use Particle Mass Comparison from four equivalent vehicle pairs compliant with current U.S. and U.K.

Source: Emissions Analytics, The Septillion Particle Problem, https://www.emissionsanalytics.com/news/the-septillion-particle-problem-literally

In addition, future Euro 7 standards are expected to further tighten the particle number limit to $1x10^{11}$ per km (ca. <0.5 mg/mile) and regulate solid ultrafine particles down to 10 nm in diameter[7] to reflect the feasibility of the control technologies. Euro 7 regulations will likely also expand the operating window to include lower temperature operation, higher altitude and towing. In anticipation of these tighter limits over extended duty operation, suppliers have improved fuel injection as well as diesel and gasoline particulate filters and some OEMs are already achieving these tighter limits in Europe as presented by the CLOVE consortium to the Advisory Group on Vehicle Emission Standards in 2020[7]. MECA was part of that advisory group and would be happy to share that information with CARB staff.

CARB staff have proposed to tighten both the FTP and stand alone US06 NMOG+NOx standards to equivalent fleet average standard of 30 mg/mile. However, with regards to PM2.5, staff is proposing non-equivalent standards of 1.0 mg/mile over the FTP and only 3 mg/mile over the US06. As previously noted, this is far less protective than particle number standards in the European Union, China and India which equate on a mass basis to approximately 0.5 mg/mile.

MECA supports that lower equivalent PM emissions standards of approximately 0.5 mg/mile are readily achievable by all passenger cars (PCs), light duty trucks (LDTs) and medium passenger vehicles (MPVs) over both the FTP and US06 certification test cycles. It should be noted that during the ACC rulemaking, CARB worked with EPA to determine the feasibility of PM mass measurement at very low emissions levels. The agencies found that current gravimetric methods are suitable for measuring below 1 mg/mile. Given more than five years has passed since this examination, it is likely that gravimetric and other measurement methods are able to be employed to measure PM at even lower limits[8].

Examination of MY 2021 and 2022 publicly available records reveals that LDV CARB PM certification level values (corresponding to the actual test results adjusted with the deterioration factors) over the US06 cycle using LEVIII E10 fuel, average approximately 1.6 mg/mile with a sizeable portion of the fleet already below the 1.0 mg/mile level. Current full-size pick-up trucks appear to offer even lower reported average PM levels of approximately 1.2 mg/mile. Furthermore, testing by our members has shown that PM emissions substantially below 0.5 mg/mile are presently observed over the US06 cycle than the FTP cycle without the use of particle filters. This has been confirmed by results reported by CARB staff.

Based upon the breadth of best performing vehicles, an FTP and US06 PM limit of 0.5 mg/mile would continue to bring down PM emissions, which would provide significant protective air quality health benefits, particularly to disadvantaged communities near roadways and urban communities that experience high vehicle traffic. Furthermore, MECA suggests that CARB harmonize the timing of the phase in of the lower US06 PM limits to coincide with the phase-in of lower FTP limits from 2025 to 2028 in LEV III. The same technologies and engine strategies to meet the new FTP limit would be applied to meet the lower US06 limit by 2028.

Medium Duty Vehicle Proposals

Both gasoline and diesel engines feature prominently amongst medium duty vehicles which often share many attributes and powertrain platforms also certified as light-duty trucks or medium duty passenger vehicles. MECA would highlight that the proposed MDV Class 2b and Class 3 NMOG+NOx fleet averages of SULEV150 (Class 2b: 8500 to 10,000lbs) and SULEV175 (Class 3: 10,000 to 14,000lbs) still reflect fleet averages of 5 to almost 6 times higher than that proposed for light duty trucks and SUVs <8500lbs, as well as medium duty passenger vehicles. This despite the fact that Class 2b and 3 vehicles have gross vehicle weights that are equivalent to no more than 18% to 65% heavier.

Table 2. EPA Certified Levels of Class 2b and 3 Medium-Duty Vehicles

	EPA CERTIFIED LEVEL (mg/mile)			
	NMOG+NOx		PM	
Class 2B	Gasoline	Diesel	Gasoline	Diesel
FTP- AVERAGE	105	134	1.9	2 (1*)
FTP- BEST IN CLASS	24	86	0.4	0 (0.1*)
FTP- WORST IN CLASS	176	180	4	4 (1.1*)
US06 AVERAGE	67	200	2.6	2.2 (0.9*)
US06 BEST IN CLASS	29	10	1	1 (0.4*)
US06 WORST IN CLASS	156	375	6	5 (1.5*)
Class 3				
FTP- AVERAGE	153	163	4	2.4 (0.6)
FTP- BEST IN CLASS	74	142	1	1 (0.3*)
FTP- WORST IN CLASS	241	190	8	4 (1.1*)
LA92 AVERAGE	77	157	2.7	1.8 (0.8)
LA92 BEST IN CLASS	22	10	2	0 (0*)
LA92 WORST IN CLASS	135	284	3	3 (1.7*)

**rounded PM emission result for DPF equipped engines certifying to higher Certified Levels*

Regarding Class 2b and 3 gasoline-fueled vehicles, MECA's review of available EPA FTP NMOG+NOx certification data[9], shown in Table 2 above, indicates ranges in certification level value (corresponding to the actual test results combined with the deterioration factors) of 24 to 176 mg/mile (average ca. 105 mg/mile) for Class 2b and 74 to 241 mg/mile (average ca. 153 mg/mile) for Class 3.

Our review of available EPA FTP certification data for Class 2b and 3 diesel-fueled vehicles finds current reported ranges in certification level value (corresponding to the actual test results combined with the deterioration factors) of 86 to 180 mg/mile (average ca. 134 mg/mile) for Class 2b and 142 to 190 mg/mile (average ca. 163 mg/mile) for Class 3 vehicles.

Given the proportional vehicle weights, reported NMOG+NOx certification values of best-in-class performers, as well as, the need to provide further air quality benefits, MECA believes gasoline and diesel fueled medium-duty vehicles are capable of complying with lower NMOG+NOx standards. We encourage CARB staff to consider further correlational analysis between the Omnibus and LEV III/IV light-duty standards for Class 2b and Class 3 medium duty vehicles to ensure a comparable and ambitious medium-duty fleet average is set.

MECA also suggests equivalent certification limits be set over the applicable US06 test cycle portion (full US06 or US06 Bag 2 for Class 2B) and LA-92 (Class 3) test cycles in these weight classes to ensure robust calibration and emissions control performance.

With regards to proposed ACC II PM standards for medium-duty vehicles, the reported certification level ranges (actual result plus deterioration factors) for gasoline fueled Class 2b vehicles are 0.4 to 4 mg/mile (average 1.9 mg/mile) and for Class 3 vehicles are 1 to 8 mg/mile (average 4 mg/mile). Over the more aggressive US06 cycle, Class 2b gasoline fueled vehicles report values of 1.0 to 6 mg/mile while Class 3 vehicles report values of 2 to 3 mg/mile over the LA92 cycle. With reference to the table above, diesel vehicles are reporting comparable certified levels of PM, however, the actual rounded emissions results (Table 1 values above denoted with *) are considerably lower reflecting the presence of Diesel Particulate Filters (DPFs).

Given the current certification values of best-in-class gasoline-fueled performers, and available proven technologies to reduce PM from both gasoline and diesel vehicles, such as advanced high pressure fuel injectors and GPFs/DPFs, more stringent PM standards for Class 2b and Class 3 gasoline and diesel fueled vehicles can be readily achieved than are proposed in this regulation. In addition, as fuel efficiency standards tighten and GDI injection technology becomes more common on commercial vehicle gasoline engines, the actual real-world PM emissions from medium-duty gasoline engines are likely to increase in the absence of tighter PM standards.

Commercially Available Technologies Support Tighter Medium Duty Standards

Technologies are commercially available to ensure that MD gasoline and diesel fueled engines can meet more stringent NMOG+NOx and PM standards.

Medium-duty vehicles with Gasoline Engines

Historically, spark-ignition engine FTP tests have shown that the majority of NMHC, CO, and NOx emissions occur during the cold start phase; however, emissions during warmed-up and hot operation, specifically during high-load operation, can also significantly contribute to emissions, especially with heavier MD and HD vehicles.

There are a variety of measures that can be utilized on spark-ignition gasoline engines to further reduce emissions. These include;

Engine Mapping and Calibration

In order to comply with lower NMOG+NOX and PM emissions standards over certification cycles such as the FTP, US06, SC03, and LA92, manufacturers will employ improved engine maps and calibration strategies of existing engines and emission control related systems. Other design changes to system architecture can be deployed to manage engine-out emissions and exhaust flows, reduce catalyst light-off times, increase exhaust temperatures during periods of low-load or idle and reduce excessive warmed-up and hot running emissions to protect engine and emission control components which are susceptible to deterioration from extended exposure to severe exhaust temperatures.

Exhaust Emission Control Technologies

Several emissions control choices can be made to improve and optimize emissions control performance. For gasoline engines, the technology base of advanced three-way catalysts deposited on high cell density (as high as 1200 cells/in^2), thin-walled substrates (approaching 0.05mm) have evolved dramatically for light- and medium-duty chassis certified vehicles to comply with Tier 3/LEV 3 standards. Recent advances have yielded high porosity, low thermal mass substrates with narrow pore size distributions, which enable high emissions reduction efficiency with less precious metal loading [10, 11]. Catalyst manufacturers have also developed coating techniques based on layered or zoned architectures to strategically deposit precious metals in ways that optimizes their performance at a minimum of cost. These advanced catalysts are then packaged using specially designed matting materials and passive thermal management strategies which can be used to allow chassis certified medium-duty trucks to meet the stringent Tier 3 emission fleet average limit of 30 mg/mile or approximately 100 mg/bhp-hr.

Reducing Cold Start Emissions

Close-coupled catalyst exhaust architectures (with or without a secondary underfloor converter) have been used on light-duty vehicles starting with Tier 2 LDV standards and are an effective strategy for addressing cold-start or low-load operation.

Secondary air injection can also be used to accelerate catalyst activation under cold-start conditions in spark ignition engines. Using a richer air/fuel ratio via intake air throttling, retarding fuel injection, or post combustion in-cylinder fuel additions during the exhaust stroke while injecting air directly into the exhaust port of the engine, results in excess fuel combustion within the exhaust manifold, creating additional heat that results in increasing catalyst temperatures to achieve faster catalyst light-off. These strategies can also be coupled with exhaust gas recirculation.

Spark-ignition engines that employ a richer cold start calibration used in combination with a secondary air injection system experience improved combustion stability. In addition, the richer calibration is less sensitive to variations in fuel volatility since less volatile fuels may lead to poor start and idle performance on engines calibrated to run lean during cold operation[12,13] (Serrano, et al., 2009) (Lee & Heywood, 2010).

In support of the Tier 3 light-duty regulation[14], EPA tested a 2011 LDT4 pick-up truck with a 5.3L V8 engine that included a MECA supplied aftertreatment system. The aftertreatment package consisted of advanced catalyst coating on 900 cpsi substrates in the close-coupled location as well as underfloor catalysts and was aged to 150,000 miles. The system was combined with cylinder deactivation and achieved an FTP NMHC+NOx level of 18 mg/mile. We believe that these same technology approaches can be deployed on medium-duty gasoline engines to meet more stringent emission levels than those being currently proposed.

Operation Under High Loads

Heavier MD and HD gasoline vehicles can operate at higher loads and exhaust temperatures (i.e. due to towing) which can impact catalyst durability. Moving the catalytic converter closer to the exhaust manifold to improve cold start performance can result in increasing the time it is exposed to higher temperatures under higher load conditions. Manufacturers may use fuel enrichment modes to ensure cylinder head, exhaust manifold and catalyst temperatures are maintained below design durability thresholds. Using fuel enrichment to control catalyst temperature while effective, can cause significant increases in criteria pollutant emissions and also significant increases in fuel consumption.

Catalyst manufacturers have continued to improve the stability of supporting catalyst washcoats and performance of precious metal catalysts under higher exhaust temperatures that occur when converters are close coupled to reduce the need to employ fuel enrichment modes. Modern gasoline engines also have several design, calibration and additional technologies that could be used to reduce the occurrence of higher exhaust temperatures by modifying combustion or load characteristics. Examples of engine-based technologies include exhaust gas recirculation (EGR), modified valve timing, electronic throttle airflow, cylinder deactivation, cylinder heads with improved cooling and exhaust manifolds which are partially integrated into the cylinder head, and cooled exhaust manifolds.

In addition, engine down-speeding or governing of the engine operating range can reduce exhaust temperatures and the need to employ enrichment for thermal protection. This strategy will allow the emission controls to remain in stoichiometric air-fuel control (i.e. closed loop) where the catalysts can maintain peak emissions reduction efficiency for a broader range of operation.

Finally, it is possible to replace a close-coupled catalyst with an electrically heated TWC (EHC) or electric heater (EH) located in front of a TWC in a downstream location farther from the engine in order to protect it from thermal exposure during times of high engine load. An EHC or EH can employ electrically generated heat to improve catalyst light-off, especially at cold start and times of low exhaust temperature. This configuration is further enabled by 48-volt system architectures described in more detail below.

In 2005, MECA applied some of the above-mentioned strategies to two full-sized 2004 pick-up trucks equipped with a 5.4L and 6.0L engine[15]. The aftertreatment systems were packaged with dual-wall insulated exhaust systems and fully aged to represent 120,000 miles of real-world operation. Even with 15-year-old engine technology and limited engine calibration on one of the vehicles, both vehicles achieved FTP NMHC+NOx emissions of 60-70 mg/mile. Although the cast-iron exhaust manifolds on these vehicles were retained, an OEM likely would take advantage of such cost effective passive thermal management strategies, including dual-wall insulated exhaust or integrated exhaust manifolds, to further reduce cold-start emissions.

Medium-duty Vehicles with Diesel Engines

With regards to diesel engine emissions, MECA members have been developing and commercializing a full suite of technologies to help medium and heavy-duty engine manufacturers to comply with the Omnibus and these technologies can be readily applied to medium-duty chassis certified vehicles as well. Exhaust and emission control technologies include next generation close coupled and under chassis selective catalytic reduction (SCR), oxidation and diesel soot ignition catalysts with high porosity, low thermal mass substrates with heated catalyst and urea dosing strategies. These can be combined with engine thermal management strategies such as cylinder deactivation and advanced forms of turbocharging and EGR. These technologies already exist on some passenger car applications in Europe where real driving emission test procedures demand them. We further elaborate on these technologies below.

Cylinder Deactivation and Variable Valve Actuation

Cylinder deactivation (CDA) is an established technology on light-duty gasoline vehicles, with the primary objective of reducing fuel consumption and CO_2 emissions. This technology combines hardware and software computing power to, in effect, "shut down" some of an engine's cylinders, based on the power demand, and keep the effective cylinder load in an efficient portion of the engine map without burning more fuel. Based on decades of experience with CDA on passenger cars and trucks, CDA is now being adapted for diesel engines. On a diesel engine, CDA is programmed to operate differently than on gasoline engines, with the goal of the diesel engine running hotter in low-load situations by having the pistons that are firing do more work. This programming is particularly important for vehicles that spend a lot of time in creep and idle operation modes. During low-load operation, CDA has resulted in exhaust temperatures increasing by 50°C to 100°C when it is most needed to maintain effective conversion of NOx in the selective catalytic reduction (SCR) catalyst bed. In some demonstrations, CDA has been combined with a 48V mild hybrid motor with launch and sailing capability to extend the range of CDA operation over the engine, and this may deliver multiplicative CO_2 reductions from these synergistic technologies[16].

The use of variable valve actuation (VVA) is another approach for active thermal management. VVA approaches include: early exhaust valve opening (EEVO), early intake valve closing (EIVC) or late intake valve closing (LIVC), all considered active thermal management strategies. Both EIVC and LIVC reduce the amount of air trapped at valve closing. Both methods reduce the effective compression ratio and volumetric efficiency, resulting in lower NOx emissions and reduced air-fuel ratio, and in turn, hotter exhaust temperature. EEVO results in hotter exhaust gas to heat-up aftertreatment; however, more fueling is needed to maintain brake power output. This results in a CO_2 emissions penalty that must be accounted for in calibrating for better fuel economy and higher engine-out NOx during hot operation when the SCR can be used to remediate NOx emissions. VVA offers some potential cost savings and is therefore used in some medium-duty applications as a fast heat-up strategy. OEMs will have multiple pathways at varying costs to achieve their thermal management objectives and achieve ultra-low NOx emissions in low-load and low-speed operation.

Modern Turbochargers

Modern turbochargers have a variety of available design options enabling lower CO_2 emissions by improving thermal management capability, such as: i) state of the art aerodynamics, ii) electrically-actuated wastegates that allow exhaust gases to by-pass the turbocharger to increase the temperature in the aftertreatment, and iii) advanced ball bearings to improve transient boost response. These and other technologies are available to support further reductions in CO_2 and emissions. More advanced turbochargers are designed with a variable nozzle that adjusts with exhaust flow to provide more control of intake pressure and optimization of the air-to-fuel ratio for improved performance (e.g., improved torque at lower speeds) and fuel economy. These variable geometry turbochargers (VGT), also known as variable nozzle turbines (VNT) and variable turbine geometry (VTG), also enable lower CO_2 emissions through improved thermal management capability to enhance aftertreatment light-off. Finally, modern turbochargers have enabled engine and vehicle manufacturers the ability to downsize engines, resulting in fuel savings without sacrificing power and/or performance. The latest high-efficiency turbochargers are one of the more effective tools demonstrated in the DOE SuperTruck program[17]. In addition to affecting the power density of the engine, turbochargers play a significant role in NOx and CO_2 regulations compliance. Continuous improvement in turbocharger technology is making it possible to run very lean combustion (high air/fuel ratios), which increases efficiency. This improvement allows for very low particulate generation and even lower engine-out NOx.

Turbo-compounding

Turbo-compounding is a variant of turbocharger technology that allows for the energy from the exhaust gas to be extracted, converted to mechanical energy and added to the engine crankshaft through a transmission. Mechanical turbo-compounding has been employed on some commercial diesel engines, and EPA estimated penetration to reach 10% in the U.S. by the time the Phase 2 GHG Regulation is fully implemented in 2027[18]. An early 2014 version of a turbo-compound-equipped engine was used during the first stage of testing at SwRI under the CARB HD Low NOx Test Program, and the results from this engine with advanced aftertreatment have been summarized in several SAE technical papers[19,20,21]. While turbo-compounding has the potential to reduce fuel consumption, it can result in lower exhaust temperatures that can challenge aftertreatment performance. Therefore, it is important to consider turbo-compound designs that incorporate bypass systems during cold start and low load operation or electrically driven turbo-compounding systems where the unit can be placed after the aftertreatment system.

Driven Turbochargers

Driven turbochargers can be used to control the speed of the turbomachinery independently of the engine's exhaust flow and vary the relative ratio between engine speed and turbo speed. Driven turbochargers may be utilized for several reasons, including performance, efficiency, and emissions. Considered an 'on-demand' air device, a driven turbocharger also receives transient power from its turbine. During transient operation, a driven turbocharger will behave like a supercharger and consume mechanical or electrical energy to accelerate the turbomachinery for improved engine response. At high-speed operation, the driven turbocharger will return mechanical or electrical power to the engine in the form of turbo-compounding, which recovers excess exhaust power to improve efficiency. This cumulative effect lets a driven turbocharger perform all the functions of a supercharger, turbocharger, and turbo-compounder. NOx emission control uniquely benefits from the application of driven turbochargers in several ways, including the ability to decouple EGR from boost pressure, reduce transient engine-out NOx, and improve aftertreatment temperatures during cold start and low load operation. Bypassing a driven turbine can provide quick temperature rises for the aftertreatment while still delivering the necessary boost pressure to the engine through supercharging, which also increases the gross load on the engine to help increase exhaust temperature[22]. Testing has shown that routing engine exhaust to the aftertreatment by bypassing a turbocharger is one of the most effective methods to heat up the aftertreatment[16].

Medium-duty Vehicles employing Electrification

Mild Hybridization - 48-volt mild hybrid electrical systems and components are expected to make their way onto commercial diesel vehicles in the near future. These 48-volt systems can be found on many light-duty vehicle models (primarily in Europe) from Mercedes, Audi, VW, Renault and PSA. In the U.S., FCA is offering a 48-volt system on the RAM 1500 pick-up and the Jeep Wrangler under the eTorque trademark. Because the safe voltage threshold is 60 volts, which is especially important when technicians perform maintenance on the electrical system, 48-volt systems are advantageous from an implementation standpoint. From a cost perspective, 48-volt systems include smaller starter and wire gauge requirements, offering cost savings from a high voltage architecture of a full hybrid. The U.S. Department of Energy's SuperTruck II program teams employed 48-volt technologies on their vehicles to demonstrate trucks with greater than 55% brake thermal efficiency. A recent study demonstrated through model-based simulations that a 48-volt technology package combined with advanced aftertreatment can achieve a composite FTP emission level of 0.015 g/bhp-hr[23].

Similar to the passenger car fleet, truck OEMs are considering replacing traditionally mechanically-driven components with electric versions to gain efficiency. Running accessories off of 48-volt electricity rather than 12-volts is more efficient due to reduced electrical losses and because components that draw more power, such as pumps and fans, have increased efficiency when operating at higher voltages. The types of components that may be electrified include, electric turbos, electronic EGR pumps, AC compressors, electrically heated catalysts, electric cooling fans, oil pumps and coolant pumps, among others. Another technology that 48-volt systems could enable is electric power take-offs rather than using an engine powered auxiliary power unit or idling the main engine during hoteling while the driver rests. MECA members supplying commercial 48V components for commercial vehicles believe that the technology may be feasible to apply to a limited number of engine families by 2024, and it is likely to see greater penetration by 2027, especially on Class 8 line-haul where full hybridization is less practical.

Mild hybridization covers a range of configurations, but a promising one includes an electric motor/generator, regenerative braking, electric boost and advanced batteries. Stop/start deployment also provides a thermal management benefit to the aftertreatment by preventing cooling airflow through the aftertreatment during hot idle conditions. In this way, 48-volt mild hybridization is complementary technology to CDA and start-stop capability, allowing the combination of multiple technologies on a vehicle to yield synergistic benefits and justify the cost. By shutting off the engine at idle or motoring using start/stop, micro hybrid technology can help to maintain aftertreatment temperature by avoiding the pumping of cold air through the exhaust. Capturing braking energy and storing it in a small battery for running auxiliary components when the engine is off offers another CO_2 reducing strategy for OEMs to deploy.

In lighter medium-duty applications, advanced start-stop systems have been developed that use an induction motor in a 48-volt belt-driven starter-generator (BSG). When the engine is running, the motor, acting as a generator, will charge a separate battery. When the engine needs to be started, the motor then applies its torque via the accessory belt and cranks the engine instead of using the starter motor. The separate battery can also be recharged via a regenerative braking system. In addition to the start-stop function, a BSG system can enhance fuel economy even during highway driving by cutting off the fuel supply when cruising or decelerating. Such systems can also be designed to deliver a short power boost to the drivetrain. This boost is typically 10 to 20 kW and is limited by the capacity of the 48V battery and accessory belt linking the motor to the crankshaft. New designs are linking the BSG directly to the crankshaft and allowing additional power boost of up to 30kW to be delivered, giving greater benefits to light and medium commercial vehicles[16]

Full hybridization, plug-in hybrids and fully electric vehicles - Full hybrid configurations are currently found on several models of light-duty passenger cars and light trucks in the U.S. and a limited number of medium-duty trucks. These include PHEV models that can also be plugged-in to enable all-electric operation over a defined all-electric range (AER). A full hybrid can enable electrification of many of the components described above for mild hybrid vehicles, but the higher voltages allow for more parts to be electrified and to a larger degree of efficiency. Full hybrids implementing larger electric motors and batteries, can also support greater acceleration capability and regenerative braking power. Full hybrid vehicles have made the highest penetration into parcel delivery, beverage delivery and food distribution vehicles because they can take advantage of regenerative braking in urban driving[24]. We expect to see some application of full hybrids combined with low NOx engines to reduce CO_2 emissions in several vocational and local delivery applications. Integrated electric drivetrain systems, consisting of a fully qualified transmission, motor and power electronics controller, are now commercially available. With power levels of over 160kW and the ability to meet high torque requirements, these systems enable electrification of medium-duty commercial vehicles. There is also an increasing number of electric drivetrain solutions up to 300kW that are suitable for medium and heavy-duty vehicles that can be used with either battery or fuel cell power sources[16].

Plug-in hybrids (PHEVs) can be practical for light and medium- duty trucks (e.g., Class1 through 3) that do not travel long distances or operate for long periods of time without returning to a central location. In addition, serial plug-in hybrids which employ an engine operating only as a generator to charge the traction battery to extend range, offer operational flexibility for commercial vehicles while full electric vehicles and their needed infrastructure are established.

It is worth noting that both HEVs and PHEVs are able to achieve significant GHG benefits compared to their conventional vehicle counterparts by employing relatively low-capacity batteries as shown in Table 1 on page 3. For example, a popular HEV crossover utility vehicle with a 1.6 kWh battery provides up to 30% lower CO_2 emissions compared to an equivalent non-hybrid version. A PHEV version equipped with larger 18.1 kWh battery that enables a modest all electric range of 42 miles can provide even steeper CO_2 reductions of 60% or greater. Both of these powertrain configurations can be employed with medium duty vehicles to offer reduced GHG and criteria pollutant emissions.

To fully electrify the same medium-duty vehicle, a minimum of a 75 to 100kWh battery would be needed. One can calculate the amount of CO_2 reduced each year as a function of battery capacity (kWh) and miles driven (i.e. 10,000 miles). Using US EPA/DOE fueleconomy.gov data in Table 1 as an example, the latest generation full hybrid powertrain would yield over 700kg CO_2/kWh/year, whereas a plug-in hybrid would yield 127 kgCO_2/kWh/year and a BEV would yield 31 kgCO_2/kWh/year. This illustrates that strategically deploying HEV and PHEV powertrains as well as BEVs can yield significantly greater CO_2 reductions on a battery capacity basis thus reducing battery critical mineral supply chain pressures and providing fleets and manufacturers greater flexibility.

Medium-duty Vehicles with Renewable Natural Gas and Hydrogen Fueled Engines

CARB should allow renewable natural gas and hydrogen-fueled engines to continue as transitional ZEV technologies available to medium duty fleets that have access to these fuels. Suppliers are working with their heavy-duty customers to commercialize this technology and extending this compliance pathway in ACC II would encourage technology innovation and add flexibility in challenging applications including Class 2b and 3 work trucks that are heavily used under higher loads and towing in fleet applications.

Medium-duty In-use Compliance Program

With regards to in-use compliance, MECA remains supportive of the staff proposal that chassis certified medium duty vehicles (MDVs) should use the same in-use 3-Bin Moving Average Windows (3B-MAW) test method and standards from the Omnibus and believes this proposal is a viable way to address the current disparities between chassis and engine-based standards. Since in-use testing occurs only after vehicles have been in the field for several years, relying on compliance testing to validate the efficacy of technology could have the potential consequence for high in-use emissions to occur before the performance is verified. MECA recommends that CARB consider reviewing manufacturer-submitted in-use compliance validation testing data at the time of certification to give CARB the confidence that the technology and calibration is robust. This review would likely reduce the potential for future in-use compliance problems that may lead to recall and costly repair of vehicles from the field.

Results from the SwRI Heavy Duty Low NOx demonstration program, included diesel emission control components that were aged to current (435,000 miles) and future (800,000 miles) heavy heavy-duty durability requirements and then tested over several field duty cycles and in-use compliance results calculated with the new three bin moving average window (3B-MAW) methodology. Given durability requirements for the light heavy-duty classes are due to increase to 270,000 miles per the Omnibus, the results from 435,000 mile aged heavy-heavy duty parts could be used to extrapolate for MY 2027 and later smaller heavy-duty engines.

The results for the low load bin (Bin 2) that ranged from 0.033 to 0.048 g/bhp-hr, which provides 70% or more margin to the standard (0.15 g/bhp-hr). The results for the idle bin (Bin 1) ranged from 0.4 to 3.3 g/hr, which provides 60% or more margin to the idle standard (7.5 g/hr). These results further support that tighter in-use medium-duty vehicle standards are technically feasible and that the 3B-MAW protocol should be applicable and prevent emission backsliding over the life of the engine. This will ensure emissions are maintained as low as possible in underserved communities where low speed operation and idling operations are most likely to occur.

Even in the short time since the latest emission control system was provided to SwRI for the demonstration program, improvements continue to be made to substrates and catalysts. For example, a recent paper published at the 2022 SAE WCX conference describes development of high-porosity honeycomb substrates with thinner wall thickness and high cell density that can be coated with SCR catalyst. The combination of developments on this substrate enables higher surface area and lower thermal mass, which improves coating efficiency, reduces catalyst heat-up time, and reduces pressure drop. These result in performance improvements that are especially prominent at low temperature operation. At engine exhaust temperatures of 175℃, the NOx conversion efficiency improved by 14% compared to earlier generation substrates (Ido, et al., 2022).

Catalyst suppliers have already developed a next generation of SCR catalysts with higher NOx reduction efficiency and better durability compared to the Stage 3 parts tested in the SwRI demonstration program. Through the use of sophisticated models that incorporate the latest learnings on both thermal and chemical aging effects, it is possible to project the gains in efficiency provided by these new materials. A similar methodology was used to that discussed in the MECA 2027 white paper, incorporating exhaust information from the latest engine calibration from SwRI and an optimized dosing calibration for the new downstream SCR catalyst. The catalysts were laboratory aged both thermally and chemically using sulfur containing simulated exhaust gas to represent 435,000 miles of equivalent engine aging. The catalysts were modeled over the FTP, RMC and LLC certification cycles and demonstrated lower emissions than the Stage 3 system at SwRI. The not yet published results suggest that the latest generation SCR catalyst would provide OEMs with additional margin to a 0.02 g/bhp-hr standard.

This example of continual improvement and optimization is a testament to the ongoing innovative technology development occurring in the industry between suppliers and their OEM customers. Each time a test is run, new information is obtained and applied to the next iteration. This has been going on continually over the past 15 years of advanced emission controls on trucks. In fact, over the life of the SwRI program, catalyst suppliers have deployed new catalyst formulations and coating techniques to continually improve the durability and performance of the SCR system in order to build greater compliance margin relative to the program targets. Our industry has seen a tremendous amount of innovation on both engines and aftertreatment since the U.S. 2010 on-road diesel standards were implemented. This learning has been applied to improve manufacturing and reduce variability that has allowed systems to be downsized by about 60% and reducing their costs by about 30%.

Evaporative Controls

MECA agrees with the CARB objective to continue to reduce evaporative emissions through a stricter running loss standard and adding a requirement to control puff loss.

We believe that the most effective way to control puff loss emissions is to set a performance-based test procedure to include the measurement of both “puff” and re-fueling emissions to ensure that the canister capacity is sufficient and that the entire system operates effectively under elevated ambient temperatures. A testing procedure approach has been used by CARB for all other evaporative emission standards going back to the 1970 model year. In addition, standards based on test procedures are more readily enforceable in-use over a certified vehicle’s useful life.

Other major automotive regions have taken initial steps to control puff emissions, however, these initial test methods have limitations that we believe CARB could improve upon to capture both puff and refueling emissions. With regards to the EU standards, the primary concern is these standards allow for measurement of the puff loss using an auxiliary canister with a tolerance of +/- 0.5 grams. A SHED can also be used, but the same 0.5 g tolerance applies. The allowed +/- 0.5 g tolerances are larger than the CARB diurnal standard, so the EU procedure is not consistent with LEV III/Tier 3 zero evaporative regulations. The second concern with the EU puff loss measurement method is that it is not fully representative of what occurs in-use. The EU method measures the canister puff loss at the peak of a diurnal heat build, and the canister is purged prior to this heat build. In the real-world situation, the canister may be purged, but the puff will be followed by the refueling load which requires additional canister capacity. The European method only measures the puff load, not the puff plus refueling loads.

The China 6 refueling test procedure does include removal of the cap prior to refueling (in a SHED), but the cap is removed after a long soak at ambient (73 ^{o}F) with the canister disconnected during the soak, so cap removal after this long soak does not represent a true puff loss condition. In an improved test procedure, the cap would be removed while the tank is still elevated in temperature with a refueling event to follow, as in the real world.

In the absence of an appropriate test procedure for measuring puff loss emissions, CARB has proposed a design-based approach that uses an equation to define the minimum evaporative canister capacity for vehicles with sealed fuel tanks. The latest version of the equation was released with the ISOR on April 12, 2022 and is defined as the following:

Min Canister nominal working capacity (grams) $= 1.2 \times 1.3 \times [5.8 \times 14.7/P_{tvs} \times ((P_{tvs} \times V_{tvs})/14.7 - V_{tvs}) + G_{refuel} \times 0.88 \times V_{fuelcap}]$

With regards to the design-based equation, we offer the following additional observations and recommendations:

1. <u>Canister capacity and tank volume for currently certified PHEVs as compared to capacity determined using CARB minimum capacity equation:</u>

MECA reviewed the terms of the equation, and in June 2021 and January 2022, and provided written comments to CARB staff to support improving this design-based approach. Since the December 2021 workshop, staff added a new multiplicative factor of 1.2 to the equation to account for carbon deterioration and revised the $V_{fuelcap}$ term from 0.86 to 0.88.

MECA analyzed the U.S. EPA certification database[9] to obtain the EPA certified canister capacities for 10 currently certified PHEV/NIRCOS models, including the most popular and top selling models for 2021 and 2022. This data is summarized in Figure 3 and listed in Table 3 below. The EPA certified canister capacities (as retrieved from the evaporative family name codes) of the PHEV/NICROS models were then compared with the predicted minimum canister capacity from the two versions of the CARB equation using the manufacturer reported tank volume and the recommended default CARB inputs to the equations.

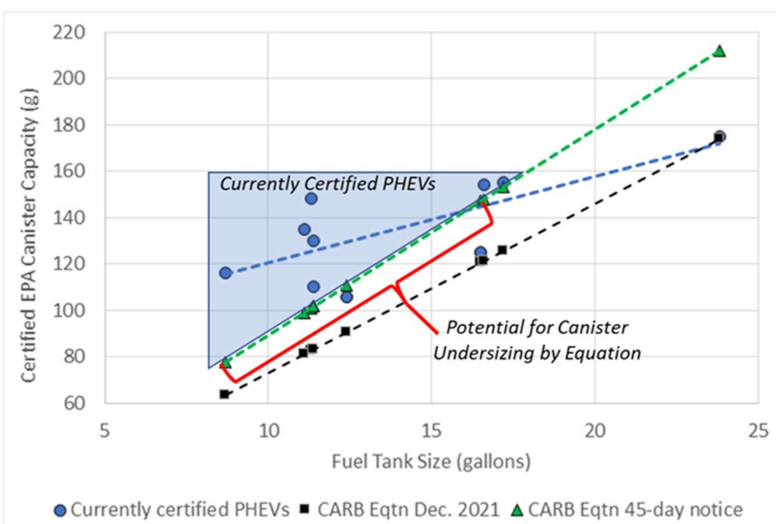

Figure 3. Comparison of Current Canister Volumes used in Certified PHEVs vs. Proposed Design-Based Equation to Size Canisters to Control Puff Losses

Figure 3 shows the calculated results from the proposed form of the equation to the currently certified canister capacities of PHEV models using sealed fuel tanks. Of particular note in Figure 3, the slope of the line predicted by the earlier form of design-based equation proposed at the December 2021 workshop (black line) does not match the slope of the certifications (blue line), which suggests an issue with the other terms of the equation that may result in the undersizing of canisters on vehicles with fuel tanks <15 gallons.

Table 3. EPA Certified Evaporative Canister Capacities Compared to Results Determined by the CARB Proposed Design-Based Equation

Vehicle Model	Nominal Tank Volume (gal)	EPA Certified Canister Capacity (g)	CARB Equation Puff + Refueling Min Canister Capacity (g)	
			Dec-21 Version	Apr-22 Version
2021 Toyota Prius Prime PHEV	11.4	130	83.2	105.6
2021 Toyota Prius Hybrid	11.3	130		
2021 Honda Clarity PHEV	7.0 – 8.7	116	51.1 - 63.5	61.6 - 76.6
2021 Honda Accord Hybrid	12.8	122		
2021 Jeep Wrangler 4XE PHEV	17.2	155	125.5	151.4
2021 Jeep Wrangler Hybrid 4DR 4x4	21.5	172		
2021 Mitsubishi Outlander PHEV	11.3	148	82.4	99.4
2020 Mitsubishi Outlander 2WD	15.8	135		
2021 Ford Escape PHEV	11.1	135	81	97.7
2021 Ford Escape FHEV	14.2	135		
2022 Kia Sorento PHEV	12.4	106	90.5	109.1
2022 Kia Sorento Hybrid	17.7	137		
2021/2022 Hyundai Ioniq PHEV	11.4	110	83.2	100.3
2021/2022 Range Rover Sport PHEV	23.8	175	173.7	209.4
2022 Range Rover Sport (Regular and MHEV)	27.6	175		
2022 Chrysler Pacifica Hybrid (PHEV)	16.5	125	120.4	145.2
2022 Chrysler Pacifica	19	140		
2022 Subaru Crosstrek PHEV	16.6	154	121.1	146.1
2022 Subaru Outback AWD	18.5	143		

The equation as presented in the 45-day notice (ISOR April 2022), bounds the lower range of the certification data for tank sizes less than 15 gallons. Although this may lead to some back sliding on canister volumes for some vehicles to the worst-in-class level, it does represent a better fit to current certification data than the December 2021 version of the equation. MECA further recommends a review of the terms discussed below and suggests adjustment of these terms to ensure a robust and accurate equation consistent with current canister volumes.

2. Suggestions for terms in the equation:

The slope of the proposed equation in Figure 3 suggests that there still remain some shortcomings with the terms in the currently proposed equation as the line underestimates the current canister sizes for fuel tanks less than 15 gallons and potentially overestimates the canister size for tanks greater than 18 gallons. MECA recommends further analysis to refine the terms based on our members expertise as discussed below.

- Carbon Deterioration Factor: As the well-established CARB test procedure to determine evaporative canister capacity uses butane working capacity (BWC) and defines capacity based on a 2 gram butane breakthrough, it is appropriate that a carbon deterioration factor also be based on tests using butane working capacity (BWC) and not gasoline working capacity (GWC). Regardless of BWC and GWC, we note that carbon deterioration does occur and inclusion of a deterioration factor is warranted. It is also appropriate to base in-use performance on BWC as well. Any reduction in the current proposed carbon deterioration value of 1.2 has the potential to result in the potential further undersizing of canisters as fuel tank volumes decrease below 15 gallons resulting in higher in-use VOC emissions.

- Definition of V_{tvs}: The proposed regulatory text defines V_{tvs} as "… % of the total geometric volume of the fuel tank. Geometric volume is the sum of the fuel tank capacity and vapor space." There are two problems in this definition. First is that the 90% factor should not be applied to the vapor space above the tank since this region of the tank always contains vapor. It should only apply to the volume identified as $V_{fuelcap}$. Second, is that the definition does not include the volume of other elements of the fuel system which would contain vapor prior to cap removal. This would include the fill pipe, the fill pipe external vent line, and any other vent lines between the tank and the canister or the tank and the tank pressure control valve located between the fuel tank and canister. We recommend that these technical deficiencies be corrected by changing the definition for V_{tvs}. These volumes are easy for manufacturers to determine and report as part of their certification application. Alternatively, CARB could offer a default value of 1.13-1.15 of $V_{fuelcap}$, since the fuel tank ullage alone is normally 12-15 percent of $V_{fuelcap}$.

- The 0.88 factor: There are two terms in the brackets in the equation. The first term is related to puff losses and the second is related to vapor displacement during refueling. The ORVR certification test requires a fill from 10% of nominal tank capacity ($V_{fuelcap}$) to nozzle automatic shut off. Given the nature of vehicle refueling, this is at least a 90% fill since automatic nozzle shut off occurs in the fill pipe. Even CARB's definition of $V_{fuelcap}$ is based on "… the volume of the fuel tank(s), specified by the manufacturer to the nearest tenth of a U.S. gallon, which may be filled with fuel from the fuel tank filler inlet." We recommend that the 0.88 value be set at 0.90, consistent with the factor used in V_{tvs}, the ORVR certification test requirement, and what occurs in use during a fill up.

As a matter of good engineering, this equation should reflect as completely and accurately as possible the emissions the canister must be expected to capture upon cap removal and a full refueling. With the lead time provided, there is ample opportunity to upgrade canister capacity to represent what better designs already achieve rather than setting a design limit that is lower than the worst-in-class vehicles today.

Conclusion

In conclusion, MECA appreciates staff's work in developing the proposed Advanced Clean Cars II regulation. We strongly support the proposal with modifications based on our comments. The proposal coupled with our suggested modifications would result in cost effective air quality benefits for millions of Californians. MECA believes that the standards are technically achievable on the timelines proposed for implementation. Our industry is prepared to do its part and deliver cost-effective and durable advanced emission control and efficiency technologies to the light-duty sector to assist in simultaneously advancing electrification of new vehicles while reducing criteria and GHG emissions from, the last remaining engine-equipped vehicles, to levels that represent existing technology performance.

Contact:
Dr. Rasto Brezny
Executive Director
Telephone: (202) 296-4797
Email: rbrezny@meca.org

cc: CARB staff- Craig Segall, Joshua Cunningham, Mike McCarthy, Belinda Chen, Shobna Sahni, Marissa Williams, Jason Gordon, Marko Jeftic

References

[1] Motor & Equipment Manufacturers Association, Moving America Forward (2013), https://www.mema.org/resource/2013-economic-impact-study-moving-america-forward

[2] US EPA Press Release, June 10, 2021, "EPA to Reexamine Health Standards for Harmful Soot that Previous Administration Left Unchanged", https://www.epa.gov/newsreleases/epa-reexamine-health-standards-harmful-soot-previous-administration-left-unchanged.

[3] World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329.

[4] Health Effects Institute Press Release, September 16, 2021, "New European Study Reports Health Effects at Air Pollution Levels Below Current Standards", https://www.healtheffects.org/announcements/hei-study-europe-finds-evidence-health-effects-lower-levels-air-pollution.

[5] Tessum et. Al., Sci. Adv. 7, eabf4491 (2021) U. Illinois at Urbana-Champaign, U. Washington, UT Austin, UC Berkeley, U. Minnesota, https://www.science.org/doi/10.1126/sciadv.abf4491.

[6] Molden, N., Emissions Analytics, The Septillion Particle Problem, https://www.emissionsanalytics.com/news/the-septillion-particle-problem-literally.

[7] CLOVE consortium Preliminary findings on possible Euro 7 emission limits for LD and HD vehicles, Online AGVES Meeting, October 27, 2020, https://circabc.europa.eu/sd/a/fdd70a2d-b50a-4d0b-a92a-e64d41d0e947/CLOVE%20test%20limits%20AGVES%202020-10-27%20final%20vs2.pdf.

[8] California Air Resources Board, "An Update on the Measurement of PM Emissions at LEV III Levels", https://ww2.arb.ca.gov/sites/default/files/2020-01/lev_iii_pm_measurement_feasibility _ tsd_ 20151008_ac.pdf.

[9] US EPA Light-Duty Vehicle Certification Database, https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment.

[10] T. Asako, D. Saito, T. Hirao and E. Popp, "Achieving SULEV30 Regulation Requirement with Three-Way Catalyst on High-Porosity Substrate while Reducing Platinum Group Metal Loading (SAE 2022-01-0543)," in SAE WCX, Detroit, MI, 2022.

[11] J. Warkins, T. Tao, M. Shen and S. Lyu, "Application of Low-Mass Corning FLORA Substrates for Cold-Start Emissions Reduction to Meet Upcoming LEV III SULEV30 Regulation Requirement (SAE 2020-01-0652)," in SAE WCX, Detroit, MI, 2020.

[12] Serrano, D., Lavy, J., Kleeman, A., Zinola, S., Dumas, J., Le Mirronet, S., & Heitz, D. (2009). Post Oxidation Study During Secondary Exhaust Air Injection for Fast Catalyst Light-Off (SAE 2009-01-2706).

[13] Lee, D., & Heywood, J. (2010). Effects of Secondary Air Injection During Cold Start of SI Engines (SAE 2010-01-2124).

[14] U.S. EPA, "EPA," March 2013. [Online]. Available: https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-and-related-materials-control-air-pollution.

[15] J. W. Anthony and J. E. Kubsh, "The Potential for Achieving Low Hydrocarbon and NOx Exhaust Emissions from Large Light-Duty Gasoline Vehicles," in SAE Technical Paper 2007-01-1261, 2007.

[16] MECA, "Technology Feasibility for Heavy-Duty Diesel Trucks in Achieving 90% Lower NOx Standards in 2027," 2020. Online at https://www.meca.org/wp-content/uploads/ resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf.

[17] Navistar, "Final Scientific/Technical Report for SuperTruck Project: Development and Demonstration of a Fuel-Efficient, Class 8 Tractor & Trailer Engine System," 2016.

[18] U.S. EPA, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles -- Phase 2," Federal Register, pp. 73478-74274, 25 October 2016.

[19] C. Sharp, C. C. Webb, G. Neely, J. V. Sarlashkar, S. B. Rengarajan, S. Yoon, C. Henry and B. Zavala, "Achieving Ultra Low NOx Emissions Levels with a 2017 Heavy-Duty On-Highway TC Diesel Engine and an Advanced Technology Emissions System - NOx Management Strategies (SAE 2017-01-0958)," SAE International Journal of Engines, vol. 10, no. 4, pp. 1736-1748, 2017.

[20] C. Sharp, C. C. Webb, G. Neely, M. Carter, S. Yoon and C. Henry, "Achieving Ultra Low NOx Emissions Levels with a 2017 Heavy-Duty On-Highway TC Diesel Engine and an Advanced

Technology Emissions System - Thermal Management Strategies (SAE 2017-01-0954)," SAE International Journal of Engines, vol. 10, no. 4, pp. 1697-1712, 2017.

[21] C. Sharp, C. C. Webb, S. Yoon, M. Carter and C. Henry, "Achieving Ultra Low NOx Emissions Levels with a 2017 Heavy-Duty On-Highway TC Diesel Engine - Comparison of Advanced Technology Approaches (SAE 2017-01-0956)," SAE International Journal of Engines, vol. 10, no. 4, pp. 1722-1735, 2017.

[22] J. Brin, J. Keim, E. Christensen, S. Holman and T. Waldron, "Applying a Driven Turbocharger to Improve Diesel NOx Conversion," in SAE WCX, Detroit, MI, 2022.

[23] F. Dhanraj, M. Dahodwala, S. Joshi, E. Koehler, M. Franke and D. Tomazic, "Evaluation of 48V Technologies to Meet Future CO2 and Low NOx Emission Regulations for Medium Heavy-Duty Diesel Engines (2022-01-0555)," in SAE WCX, Detroit, MI, 2022.

[24] CARB, "Draft Technology Assessment: Heavy-Duty Hybrid Vehicles," 2015.