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ENVIRONMENTAL PROTECTION AGENCY

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RIN 2060-AU41

Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine Standards

AGENCY: Environmental Protection Agency (EPA).

ACTION: Advance Notice of Proposed Rule.

SUMMARY: The Environmental Protection Agency (EPA) is soliciting pre-proposal comments on a rulemaking effort known as the Cleaner Trucks Initiative (CTI). This advance notice describes EPA's plans for a new rulemaking that would establish new emission standards for oxides of nitrogen (NOx) and other pollutants for highway heavy-duty engines. It also describes opportunities to streamline and improve certification procedures to reduce costs for engine manufacturers. The EPA is seeking input on this effort from the public, including all interested stakeholders, to inform the development of a subsequent notice of proposed rulemaking.

DATES: Comments: Comments must be received on or before [INSERT DATE 30 DAYS AFTER PUBLICATION IN THE FEDERAL REGISTER].

ADDRESSES: Comments. Submit your comments, identified by Docket ID No. EPA-HQ-OAR-2019-0055, at http://www.regulations.gov. Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from Regulations.gov. The

submissions, and general guidance on making effective comments, please visit https://www.epa.gov/dockets/commenting-epa-dockets.

Docket. EPA has established a docket for this action under Docket ID No. EPA-HQ-OAR-2019-0055. All documents in the docket are listed on the www.regulations.gov web site. Although listed in the index, some information is not publicly available, e.g., CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically in www.regulations.gov or in hard copy at Air and Radiation Docket and Information Center, EPA Docket Center, EPA/DC, EPA WJC West Building, 1301 Constitution Ave., N.W., Room 3334, Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the Air Docket is (202) 566-1742.

FOR FURTHER INFORMATION CONTACT:

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I. Introduction

On November 13, 2018, EPA announced plans to undertake a new rulemaking – the Cleaner Trucks Initiative (CTI) – to update standards for oxides of nitrogen (NOx) emissions from highway heavy-duty vehicles and engines.[1] Although NOx emissions in the U.S. have dropped by more than 40 percent over the past decade, we project that heavy-duty vehicles continue to be one of the largest contributors to the mobile source NOx inventory in 2028.[2] Reducing NOx emissions from highway heavy-duty trucks and buses is thus an important component of improving air quality nationwide and reducing public health and welfare effects associated with these pollutants, especially for vulnerable populations and lifestages, and in highly-impacted regions.

Section 202(a)(1) of the Clean Air Act (the Act) requires the EPA to set emission standards for air pollutants, including oxides of nitrogen (NOx), from new motor vehicles or new motor vehicle engines, which the Administrator has found cause air pollution that may endanger public health or welfare. Under section 202(a)(3)(A) of the Act, NOx (and certain other) emission standards for heavy-duty vehicles and engines are to "reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year to which such standards apply, giving appropriate consideration to cost, energy, and safety factors associated with the application of such technology." Section 202(a)(3)(C) requires that standards apply for no less than 3 model years and apply no earlier than 4 years after promulgation.

[1] EPA's regulations generally classify vehicles with Gross Vehicle Weight Ratings (GVWRs) above 8,500 pounds (i.e., Class 2b and above) as heavy-duty vehicles, including large pick-up trucks and vans, a variety of "work trucks" designed for vocational applications, and combination tractor-trailers.

[2] U.S. Environmental Protection Agency. "Air Emissions Modeling: 2016v1 Platform." Available online at: https://www.epa.gov/air-emissions-modeling/2016v1-platform

Given the continued contribution of heavy-duty trucks to the NOx inventory, more than 20 organizations, including state and local air agencies from across the country, petitioned EPA in the summer of 2016 to develop more stringent NOx emission standards for on-road heavy-duty engines.[3] Among the reasons stated by the petitioners for EPA rulemaking was the need for NOx emission reductions to reduce adverse health and welfare impacts and to help areas attain the National Ambient Air Quality Standards (NAAQS). EPA subsequently met with a wide range of stakeholders in listening sessions, during which certain themes were consistent across the range of stakeholders.[4] For example, it became clear that there is broad support for federal action in collaboration with the California Air Resources Board (CARB). So-called "50-state" standards enable technology suppliers and manufacturers to efficiently produce a single set of reliable and compliant products. There was broad acknowledgement of the value of aligning implementation of new NOx standards with existing milestones for greenhouse gas (GHG) standards under the Heavy-Duty Phase 2 GHG and fuel efficiency program ("Phase 2") (81 FR 73478, October 25, 2016). Such alignment would ensure that the GHG and fuel reductions achieved under Phase 2 are maintained and allow the regulated industry to implement GHG and NOx technologies into their products at the same time.[5]

[3] Brakora, Jessica. "Petitions to EPA for Revised NOx Standards for Heavy-Duty Engines" Memorandum to Docket EPA-HQ-OAR-2019-0055. December 4, 2019.

[4] Stakeholders included: emissions control technology suppliers; engine and vehicle manufacturers; a labor union that represents heavy-duty engine, parts, and vehicle manufacturing workers; a heavy-duty trucking fleet trade association; an owner-operator driver association; a truck dealers trade association; environmental, non-governmental organizations; states and regional air quality districts; tribal interests; California Air Resources Board (CARB); and the petitioners.

[5] The major implementation milestones for the Heavy-duty Phase 2 engine and vehicle standards are in model years 2021, 2024, and 2027.

EPA responded to the petition on December 20, 2016, noting that an opportunity exists to develop a new, harmonized national NOx reduction strategy for heavy-duty highway engines.[3] EPA emphasized the importance of scientific and technological information when determining the appropriate level and form of a future low NOx standard and highlighted the following potential components of the action:

- Lower NOx emission standards
- Improvements to test procedures and test cycles to ensure emission reductions occur in the real world, not only over the currently applicable certification test cycles
- Updated certification and in-use testing protocols
- Longer periods of mandatory emissions-related component warranties
- Consideration of longer regulatory useful life, reflecting actual in-use activity
- Consideration of rebuilding [6]
- Incentives to encourage the transition to current- and next-generation cleaner technologies as soon as possible

Since then, EPA has assembled a team to gather scientific and technical data needed to inform our proposal. We intend the CTI to be a holistic rethinking of emission standards and compliance. Within this broad goal, we will be looking to the following high-level principles to inform our approach to this rulemaking:

[6] As used here, the term "rebuilding" generally includes practices known commercially as "remanufacturing". Under 40 CFR part 1068, rebuilding refers to practices that fall short of producing a "new" engine.

- Our goal should be to reduce in-use emissions under a broad range of operating conditions[7]
- We should consider and enable effective technological solutions while carefully considering the cost impacts
- Our compliance and enforcement provisions should be fair and effective
- Our regulations should incentivize early compliance and innovation
- We should ensure a coordinated 50-state program
- We should actively engage with interested stakeholders

While these principles have been reflected in previous heavy-duty rulemakings, we nevertheless believe it is helpful to reemphasize them here as a reminder to both the agency and commenters. We welcome comment on these principles, as well as other key principles on which this rule should be based.

It is important to emphasize that this discussion represents EPA's early views and considerations on possible CTI elements. We request comment on all aspects of this advance notice. We plan to consider what we learn from the comments as we develop a Notice of Proposed Rulemaking (NPRM). Additional information can be found in the docket for this rulemaking.

II. Background

A. History of Emission Standards for Heavy-Duty Engines

[7] We address this goal in the context of National Ambient Air Quality Standards (NAAQS) nonattainment in Section II.D.

EPA began regulating emissions from heavy-duty vehicles and engines in the 1970s.[8,9] EPA created 40 CFR part 86 in 1976 to reorganize emission standards and certification requirements for light-duty and heavy-duty highway vehicles and engines. In 1985, EPA adopted new standards for heavy-duty highway engines, codifying the standards in 40 CFR part 86, subpart A. Since then, EPA has adopted several rules to set new and more stringent criteria pollutant standards for highway heavy-duty engine and vehicle emission control programs and to add or revise certification procedures.[10]

In the 1990s, EPA adopted increasingly stringent NOx, hydrocarbon, and particulate matter (PM) standards. In 1997 EPA finalized standards for heavy-duty highway diesels (62 FR 54693, October 21, 1997), effective with the 2004 model year, including a combined non-methane hydrocarbon (NMHC) and NOx standard that represented a reduction of NOx emissions by 50 percent. These NOx reductions also resulted in significant reductions in secondary nitrate particulate matter.

In early 2001, EPA finalized the 2007 Heavy-Duty Engine and Vehicle Rule (66 FR 5002, January 18, 2001) to continue addressing NOx and PM emissions from both diesel and gasoline-

[8] EPA's regulations address heavy-duty engines and vehicles separately from light-duty vehicles. Vehicles with GVWR above 8,500 pounds (Class 2b and above) are classified as heavy-duty. For criteria pollutants such as NOx, EPA generally applies the standards to the engines rather than the entire vehicles. However, for complete heavy-duty vehicles below 14,000 pounds GVWR, EPA applies standards to the whole vehicle rather than the engine; this is referred to as chassis-certification and is very similar to certification of light-duty vehicles.

[9] Emission standards for heavy-duty highway engines were first adopted by the Department of Health, Education, and Welfare in the 1960s. These standards and the corresponding certification and testing procedures were codified at 45 CFR part 1201. In 1972, shortly after EPA was created as a federal agency, EPA published new standards and updated procedures while migrating the regulations to 40 CFR part 85 as part of the effort to consolidate all the EPA regulations in a single location.

[10] U.S. Environmental Protection Agency. "EPA Emission Standards for Heavy-Duty Highway Engines and Vehicles," Available online: https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles. (last accessed December 4, 2019)

fueled highway heavy-duty engines. This rule established a comprehensive national program that regulated a heavy-duty engine and its fuel as a single system, with emission standards taking effect beginning with model year 2007 and fully phasing in by model year 2010. These standards projected the use of high-efficiency catalytic exhaust emission control devices. To ensure proper functioning of these technologies, which could be damaged by sulfur, EPA also mandated reducing the level of sulfur in highway diesel fuel by 97 percent by mid-2006. These actions resulted in engines that emit PM and NOx emissions at levels 90 percent and 95 percent below emission levels from then-current highway heavy-duty engines, respectively. The PM standard for new highway heavy-duty engines was set at 0.01 grams per brake-horsepower-hour (g/hp-hr) by 2007 model year and the NOx and NMHC standards of 0.20 g/hp-hr and 0.14 g/hp-hr, respectively, were set to phase in between 2007 and 2010. In finalizing this rule, EPA estimated that the emission reductions would achieve significant health and environmental impacts, and total monetized $PM_{2.5}$- and ozone-related benefits of the program would exceed $70 billion, versus program costs of $4 billion (1999$).

In 2009, as advanced emissions control systems were being introduced to meet the 2007/2010 standards, EPA promulgated a final rule to require that these advanced emissions control systems be monitored for malfunctions via an onboard diagnostic (OBD) system (74 FR 8310, February 24, 2009). The rule, which has been fully phased in, required engine manufacturers to install OBD systems that monitor the functioning of emission control components on new engines and alert the vehicle operator to any detected need for emission related repair. It also required that manufacturers make available to the service and repair industry information necessary to perform repair and maintenance service on OBD systems and other emission related engine components.

Also in 2009, EPA and Department of Transportation's National Highway Traffic Safety Administration (NHTSA) began working on a joint regulatory program to reduce greenhouse gas emissions (GHGs) and fuel consumption from heavy-duty vehicles and engines.[11] By utilizing regulatory approaches recommended by the National Academy of Sciences, the first phase ("Phase 1") of the GHG and fuel efficiency program was finalized in 2011 (76 FR 57106, September 15, 2011).[12] The Phase 1 program, spanning implementation from model years 2014 to 2018, included separate standards for highway heavy-duty vehicles and heavy-duty engines. The program offered flexibility allowing manufacturers to attain these standards through a mix of technologies, and the use of various emissions credit averaging and banking programs.

In 2016, EPA and NHTSA finalized the Heavy-Duty Phase 2 GHG and fuel efficiency program (81 FR 73478, October 25, 2016). Phase 2 includes technology-advancing performance-based standards that will phase in over the long-term, with initial standards for most vehicles and engines commencing in model year 2021, increasing in stringency in model year 2024, and culminating in model year 2027 standards. Phase 2 builds on and advances the Phase 1 program

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[11] Greenhouse gas emissions from heavy-duty engines are primarily carbon dioxide (CO_2), but also include methane (CH_4) and nitrous oxide (N_2O). Because CO_2 is formed from the combustion of fuel, it is directly related to fuel consumption. References in this notice to increasing or decreasing CO2 can be taken to be qualitative references to fuel consumption as well.

[12] The National Academies' Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles; National Research Council; Transportation Research Board. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010. Available online: https://www.nap.edu/catalog/12845/technologies-and-approaches-to-reducing-the-fuel-consumption-of-medium-and-heavy-duty-vehicles

and includes standards based not only on currently available technologies but also on technologies under development or not yet widely deployed. To ensure adequate time for technology development, Phase 2 provided up to 10 years lead time to allow for the development and phase in of these controls, further encouraging innovation and providing transitional flexibility.

B. NOx Emissions from Current Heavy-Duty Engines

For heavy-duty vehicles, EPA generally applies non-GHG emission standards to engines rather than the entire vehicles. However, most of the Class 2b and 3 pickup trucks and vans (vehicles with a Gross Vehicle Weight Rating (GVWR) between 8,500 and 14,000 pounds) are certified as complete heavy-duty vehicles; this is referred to as chassis-certification and is very similar to certification of light-duty vehicles. In fact, these chassis-certified vehicles are covered by standards in EPA's Tier 3 program, which primarily covers light-duty vehicles (79 FR 23414, April 28, 2014; 80 FR 0978, February 19, 2015). We do not intend to propose changes to the standards or test procedures for chassis-certified heavy-duty vehicles. Instead, the CTI will focus on engine-certified products.

1. **Diesel Engines**

As outlined in the previous section, the current heavy-duty engine emission standards reduced PM and NOx tailpipe emissions by over 90 percent for emissions measured using the specified test procedures, but their impact on in-use emissions during real-world operation is less clear. The diesel particulate filters (DPFs) that manufacturers are using to control PM emissions have reduced PM emissions to very low levels during virtually all types of operation. However, while the selective catalytic reduction (SCR) systems used to control NOx emissions can achieve very low levels during most operation, there remain operating modes where the SCR systems are much less effective.[13,14] For example, NOx emissions can be significantly higher during engine warm-up, idling, and certain other types of operation that result in low load on the engine or transitioning from low to high loads. Moreover, deterioration of emission controls in-use, along with tampering and mal-maintenance, can result in additional NOx emissions. In addition to tailpipe emissions, diesel engines with unsealed crankcases generally emit a small amount of exhaust-related emissions when venting blowby gases from the crankcase. Each of these sources of higher emissions presents an opportunity for additional reduction and we introduce potential solutions in Section III.A.1.

2. Gasoline Engines

Heavy-duty gasoline engines rely on three-way catalysts (TWC) to simultaneously reduce HC, CO, and NOx. This is the same type of technology used for passenger cars and light-duty trucks. Once the TWC has reached its light-off temperature,[15] it can achieve very low emission levels if the fuel-air ratio of the engine is properly controlled and calibrated. However, the application of TWC technology to heavy-duty gasoline engines and vehicles is less optimized for emissions than for light-duty. Accordingly, from start-up until the system reaches its light-off

[13] Hamady, Fakhri, Duncan, Alan. "A Comprehensive Study of Manufacturers In-Use Testing Data Collected from Heavy-Duty Diesel Engines Using Portable Emissions Measurement System (PEMS)". 29th CRC Real World Emissions Workshop, March 10 -13, 2019

[14] Sandhu, Gurdas, et al. "Identifying Areas of High NOx Operation in Heavy-Duty Vehicles". 28th CRC Real-World Emissions Workshop, March 18-21, 2018.

[15] The "light-off" temperature is nominally the temperature at which a catalyst becomes hot enough to begin functioning effectively.

temperature, emissions are elevated. Technologies and strategies that accelerate TWC light-off could reduce start-up emissions from heavy-duty gasoline engines.

Additionally, the maximum temperature thresholds that today's heavy-duty TWCs are designed to tolerate could be exceeded by gasoline engine exhaust temperatures during high-load stoichiometric operation. Consequently, heavy-duty manufacturers often implement enrichment-based strategies for engine and catalyst protection at high load. Enrichment, which is accomplished by injecting additional fuel and temporarily shifting to a rich fuel-air ratio, has long been used in gasoline engine operation to cool excessive exhaust gas temperatures to protect vital engine and exhaust components such as exhaust valves, manifolds, and catalysts. However, enrichment also results in higher emissions, including HC, CO, and PM. Technologies or strategies that expand the TWC operating temperature range could reduce the need for enrichment and further reduce emissions from heavy-duty gasoline engines.

C. Existing Heavy-Duty Compliance Cost Elements

Manufacturers have incurred significant costs over the years to reduce emissions from heavy-duty engines and costs will be an important aspect of the CTI as we consider new standards and other compliance provisions. This Section C is an overview of current types of costs, which is intended to provide context for later discussions throughout this ANPR.

The majority of the costs to comply with emission standards are directly related to the emission control technologies used by manufacturers. Technology costs include both the pre-production costs for activities such as research and development (R&D) and the costs to produce and warranty emission control components. Vehicle owners and operators may also incur costs related to compliance with emission standards if the requirements impact operating costs. EPA will evaluate technology and operating costs as part of the technological feasibility and cost analysis for new standards in the NPRM.

The remaining compliance costs for manufacturers are primarily associated with testing, reporting and recordkeeping to demonstrate and assure compliance. As a part of the CTI, we intend to evaluate these costs and identify opportunities to lower them by streamlining our compliance processes. (See Section III.F.) These non-technological costs occur in three broad categories:

1. Pre-certification emission testing.
2. Certification reporting.
3. Post-certification testing, reporting, and recordkeeping.

The Clean Air Act requires manufacturers wishing to sell heavy-duty engines in the U.S. to obtain emission Certificates of Conformity each year. To do so, manufacturers must submit an application for certification to EPA for each family of engines.[16] As specified in 40 CFR 86.007-21 and 1036.205, manufacturers must include a significant amount of information and emission test results to demonstrate to EPA that their engines will meet the applicable emission standards and related requirements.

Although most compliance costs occur before and during certification, manufacturers incur additional costs after certification. Manufacturers may be required to test a sample of production

[16] An engine family is a group of engines with similar emission characteristics as defined in 40 CFR 86.001-24 and related sections.

engines during the model year, as well as vehicles in actual use (see Sections III.B and III.C). Manufacturers must also submit end-of-year production reports. Finally, manufacturers must maintain compliance records for up to eight years.

D. The Need for Additional NOx Control

As noted in the Introduction, emissions of criteria pollutants have been declining over time due to federal, state, and local regulations and voluntary programs.[17] However, there continues to be a need for additional NO_X emission reductions in spite of the significant technological progress made to-date.[18] NO_X is a criteria pollutant, as well as a precursor to ozone and $PM_{2.5}$, and as such NO_X emissions contribute to ambient pollution that adversely affects human health (including vulnerable populations and lifestages, which are relevant to both children's health and environmental justice issues) and the environment. EPA has set primary and secondary NAAQS for each of these pollutants designed to protect public health and welfare. As of September 30, 2019, more than 128 million people lived in counties designated nonattainment for the ozone or $PM_{2.5}$ NAAQS, and additional people live in areas with a risk of exceeding those NAAQS in the future.[19] Reductions in NOx emissions will help areas attain and maintain the ozone and $PM_{2.5}$ NAAQS and help prevent future nonattainment. Reducing NOx emissions will

[17] EPA publishes an annual air trends report in the form of an interactive web application (https://gispub.epa.gov/air/trendsreport/2019/).

[18] Davidson, K., Zawacki, M. Memorandum to Docket EPA-HQ-OAR-2019-0055. "Health and Environmental Effects of NOx, Ozone and PM" October 22, 2019.

[19] EPA publishes information on nonattainment areas on its green book website (https://www3.epa.gov/airquality/greenbook/popexp.html). This data comes from the Summary Nonattainment Area Population Exposure Report, current as of September 30, 2019.

result in improved health outcomes attributable to lower ozone and particulate matter concentrations in communities across the United States.

Human health impacts of concern are associated with exposures to NO_X, ozone, and $PM_{2.5}$.[20,21,22,23] Short-term exposures to NO_2 (an oxide of nitrogen) can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms, hospital admissions and emergency department visits. Long-term exposures to NO_2 have been shown to contribute to asthma development and may also increase susceptibility to respiratory infections. Ozone exposure reduces lung function and causes respiratory symptoms, such as coughing and shortness of breath. Ozone exposure also aggravates asthma and lung diseases such as emphysema, leading to increased medication use, hospital admissions, and emergency department visits. Exposures to $PM_{2.5}$ can cause harmful effects on the cardiovascular system, including heart attacks and strokes. These effects can result in emergency department visits, hospitalizations and, in some cases, premature death. PM exposures are also linked to harmful respiratory effects, including asthma attacks. Moreover, many groups are at greater risk than healthy people from these pollutants, including: people with heart or lung disease, outdoor workers and the lifestages of older adults and children. Environmental impacts of concern are

[20] U.S. EPA. Integrated Science Assessment (ISA) For Oxides Of Nitrogen – Health Criteria (Final Report, 2016). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/068, 2016.

[21] U.S. EPA. Integrated Science Assessment (ISA) of Ozone and Related Photochemical Oxidants (Final Report, Feb 2013). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/076F, 2013.

[22] U.S. EPA. Integrated Science Assessment (ISA) For Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009.

[23] There is an ongoing review of the PM NAAQS, EPA intends to finalize the Integrated Science Assessment in late 2019 (https://www.epa.gov/naaqs/particulate-matter-pm-standards-integrated-science-assessments-current-review). There is an ongoing review of the ozone NAAQS, EPA intends to finalize the Integrated Science Assessment in early 2020 (https://www.epa.gov/naaqs/ozone-o3-standards-integrated-science-assessments-current-review).

associated with these pollutants and include light extinction, decreased tree growth, foliar injury, and acidification and eutrophication of aquatic and terrestrial systems.

Heavy-duty vehicles continue to be a significant source of NO_X emissions now and into the future. While the mobile source NO_X inventory is projected to decrease over time, recent emissions modeling indicates that heavy-duty vehicles will continue to be one of the largest contributors to mobile source NOx emissions nationwide in 2028.[24] Many state and local agencies have asked the EPA to further reduce NO_X emissions, specifically from heavy-duty engines; the importance of reducing heavy-duty NO_X emissions has been highlighted in the June 3, 2016 petition (see Section I) that was submitted to EPA and in other correspondence from stakeholders.[25,26,27,28] Pollution formed from NOx emissions can occur and be transported far from the source of the emissions themselves, and heavy-duty trucks can travel regionally and nationally. Air quality modeling indicates that heavy-duty diesel NO_X emissions are contributing to substantial concentrations of ozone and $PM_{2.5}$ across the U.S. For example, heavy-duty diesel engine NO_X emissions are important contributors to modeled ozone and $PM_{2.5}$ concentrations across the U.S. in 2025.[29] Another recent air quality modeling analysis indicates

[24] U.S. Environmental Protection Agency. "Air Emissions Modeling: 2016v1 Platform". Available online at: https://www.epa.gov/air-emissions-modeling/2016v1-platform

[25] Ozone Transport Commission. Correspondence Regarding EPA's Tampering Policy. August 28, 2019. Available online: https://otcair.org/upload/Documents/Correspondence/EPA%20Tampering%20Policy%20Letter.pdf

[26] National Association of Clean Air Agencies letter to US EPA, June 21, 2018.

[27] South Coast Air Quality Management District. "South Coast Air Quality Management District's Support for Petitions for Further NOx Reductions from Heavy-Duty Trucks and Locomotives" Letter to US EPA, June 15, 2018.

[28] NESCAUM. "The Northeast's Need for NO_X Reductions." Presented at SAE Government Industry Meeting, April 2019.

[29] Zawacki et al, 2018. Mobile source contributions to ambient ozone and particulate matter in 2025. Vol 188, pg 129-141. Available online: https://doi.org/10.1016/j.atmosenv.2018.04.057.

that transport of ozone produced in NOx-sensitive environments impacts ozone concentrations in downwind areas, often several states away.[30] A national program to reduce NO_X emissions from heavy-duty engines would allow all states to benefit from the emission reductions and maximize the benefit for downwind states.

E. California Heavy-duty Highway Low NOx Program Development

In this section, we present a summary of the current efforts by the state of California to establish new, lower emission standards for highway heavy-duty engines and vehicles. For the past several decades, EPA and the California Air Resources Board (CARB) have worked together to reduce air pollutants from highway heavy-duty engines and vehicles by establishing harmonized emission standards for new engines and vehicles. For much of this time period, EPA has taken the lead in establishing emission standards through notice and comment rulemaking, after which CARB would adopt the same standards and test procedures. For example, EPA adopted the current heavy-duty engine NOx and PM standards in a 2001 final rule, and CARB subsequently adopted the same emission standards. EPA and CARB often cooperate during the implementation of highway heavy-duty standards. Thus, for many years the regulated industry has been able to design a single product line of engines and vehicles which can be certified to both EPA and CARB emission standards (which have been the same) and sold in all 50 states.

[30] U.S. Environmental Protection Agency: Air Quality Modeling Technical Support Document for the Final Cross State Air Pollution Rule Update. August 2016. Available online: https://www.epa.gov/sites/production/files/2017-05/documents/aq_modeling_tsd_final_csapr_update.pdf

Given the significant ozone and PM air quality challenges in the state of California, CARB has taken a number of steps to establish standards beyond the current EPA requirements to further reduce NOx emissions from heavy-duty vehicles and engines in their state. CARB's optional (voluntary) low NOx program, started in 2013, was created to encourage heavy-duty engine manufacturers to introduce technologies that emit NOx at levels below the current US 2010 standards. Under this optional program, manufacturers can certify their engines to one of three levels of stringency that are 50, 75, and 90 percent below the existing US 2010 standards, the lowest optional standard being 0.02 grams NOx per horsepower-hour (g/hp-h), which is a 90 percent reduction from today's federal standards.[31] To date, only natural gas and liquefied petroleum gas engines have been certified to the optional standards.

In May 2016, CARB published its Mobile Source Strategy outlining their approach to reduce in-state emissions from mobile sources and meet their air quality targets.[32] In November 2016, CARB held its first Public Workshop on their plans to update their heavy-duty engine and vehicle programs.[33] CARB's 2016 Workshop kicked off a technology demonstration program (the CARB "Low NOx Demonstration Program"), and announced plans to update emission standards, laboratory-based and in-use test procedures, emissions warranty, durability demonstration requirements, and regulatory useful life provisions. The initiatives introduced in

[31] California Code of Regulations, Title 13, section 1956.8.

[32] California Air Resources Board. "Mobile Source Strategy". May 2016. Available online: https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf

[33] California Air Resources Board. "Heavy-Duty Low NOx: Meetings & Workshops". Available online: https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox/heavy-duty-low-nox-meetings-workshops

their 2016 Workshop have since become components of CARB's Heavy-Duty "Omnibus" Low NOx Rulemaking.

CARB's goal for its Low NOx Demonstration Program was to investigate the feasibility of reducing NOx emissions to levels significantly below today's US 2010 standards. Southwest Research Institute (SwRI) was contracted to perform the work, which was split into three "Stages".[34] In Stage 1, SwRI demonstrated an engine technology package capable of achieving a 90 percent NOx emissions reduction on today's regulatory test cycles.[35] In Stage 1b, SwRI applied an accelerated aging process to age the Stage 1 aftertreatment components to evaluate their performance. SwRI developed and evaluated a new low load-focused engine test cycle for Stage 2. In Stage 3, SwRI is evaluating a new engine platform and different technology package to ensure emission performance. EPA has been closely following CARB's Low NOx Demonstration Program as a member of the Low NOx Advisory Group for the technology development work. The CARB Low NOx Advisory Group, which includes representatives from heavy-duty engine and aftertreatment industries, as well as from federal, state, and local governmental agencies, receives updates from SwRI on a bi-weekly basis.[36]

[34] Southwest Research Institute. "Update on Heavy-Duty Low NOx Demonstration Programs at SwRI". September 26, 2019. Available online: https://ww3.arb.ca.gov/msprog/hdlownox/files/workgroup_20190926/guest/swri_hd_low_nox_demo_programs.pdf

[35] Southwest Research Institute. "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles: Final Report". April 2017. Available online: https://ww3.arb.ca.gov/research/apr/past/13-312.pdf

[36] California Air Resources Board. "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles". May 10, 2017. Available online: https://ww3.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm

CARB has published several updates related to their Omnibus Rulemaking. In June 2018, CARB approved their "Step 1" update to California's emission control system warranty regulations.[37] Starting in model year (MY) 2022, the existing 100,000-mile warranty for all diesel engines would lengthen to 110,000 miles for engines certified as light heavy-duty, 150,000 miles for medium heavy-duty engines, and 350,000 for heavy heavy-duty engines. In November 2018, CARB approved revisions to the onboard diagnostics (OBD) requirements that include implementation of real emissions assessment logging (REAL) for heavy-duty engines and other vehicles.[38] In April 2019, CARB published a "Staff White Paper" to present their staff's assessment of the technologies they believed were feasible for medium and heavy heavy-duty diesel engines in the 2022-2026 timeframe.[39]

CARB staff are expected to present the Heavy-Duty NOx Omnibus proposal to their governing board for final approval in 2020. It is expected to include updates to their engine standards, certification test procedures, and heavy-duty in-use testing program that would take effect in model year 2024, with additional updates to warranty, durability, and useful life provisions and further reductions in standards beginning in model year 2027.

While we are not requesting comment on whether CARB should adopt these updates, we are requesting comment on the extent to which EPA should adopt similar provisions, and whether

[37] California Air Resources Board. "HD Warranty 2018" June 28, 2018. Available online: https://ww2.arb.ca.gov/rulemaking/2018/hd-warranty-2018

[38] California Air Resources Board. "Heavy-Duty OBD Regulations and Rulemaking". Available online: https://ww2.arb.ca.gov/resources/documents/heavy-duty-obd-regulations-and-rulemaking

[39] California Air Resources Board. "California Air Resources Board Staff Current Assessment of the Technical Feasibility of Lower NOx Standards and Associated Test Procedures for 2022 and Subsequent Model Year Medium-Duty and Heavy-Duty Diesel Engines". April 18, 2019. Available online: https://ww3.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf

similar EPA requirements should reflect different stringency or timing. Commenters supporting EPA requirements that differ from the expected CARB program are encouraged to address how such differences could be implemented to maintain a national program to the extent possible. For example, how important would it be to harmonize test procedures, even if we adopt different standards? Also, how might standards be aligned if stringencies are harmonized, but timing differs?

III. Potential Solutions and Program Elements

EPA's current certification and compliance programs for heavy-duty engines began in the 1970s – a period that predates advanced emission controls and electronic engine controls. Although we have made significant modifications to these programs over the years, we believe it is an appropriate time to reconsider their fundamental structures and refocus them to reflect twenty-first century technology and approaches.

As described previously, the CTI can be summarized as a holistic approach to implementing our Clean Air Act obligations. One of our high-level principles, discussed in the Introduction, is to consider and enable effective solutions and give careful consideration to the cost impacts. Within that principle, we have identified the following key goals:[40]

- Our program should not undermine the industry's plans to meet the CO_2 and fuel consumption requirements of the Heavy-duty Phase 2 program and should not adversely impact safety

[40] Our identification of these key components to consider is informed by section 202(a) of the Clean Air Act which directs EPA to establish emission standards for heavy-duty engines that "reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available" and to consider "cost, energy, and safety factors associated with the application of such technology."

- CTI should leverage "smart" communications and computing technology
- CTI will provide sufficient lead time and stability for manufacturers to meet new requirements
- CTI should streamline and modernize regulatory requirements
- CTI should support improved vehicle reliability

Commenters are encouraged to address these goals. We also welcome comments on other potential goals that should be considered for the CTI.

Keeping with our goal of providing appropriate lead time for new standards and stability of product designs, and also meeting CAA requirements, we are considering implementation of new standards beginning in model year 2027, which is also the implementation year for the final set of Heavy-Duty Phase 2 standards. This would provide four to six full model years of lead time and would allow manufacturers to implement a single redesign, aligning the final step of the Phase 2 standards with the potential new CTI requirements.

As part of our early developmental work for this rulemaking, EPA has identified technologies that we currently believe could be used to reduce NOx emissions from heavy-duty engines in the 2027 timeframe. Our early feasibility assessments for these technologies are discussed below along with potential updates to test procedures and other regulatory provisions.

Although our focus in this rulemaking is primarily on future model years, we also seek comment on the extent to which the technologies and solutions could be used by state, local, or tribal governments in reducing emissions from the existing, pre-CTI heavy-duty fleet. EPA's Clean Diesel Program, which includes grants and rebates funded under the Diesel Emissions

Reduction Act (DERA), is just one example of a partnership between EPA and stakeholders that provides incentives for upgrades and retrofits to the existing fleet of on-road and nonroad diesel vehicles and equipment to lower air pollution.[41]

A. Emission Control Technologies

This section addresses technologies that, based on our current understanding, would be available in the 2024 to 2030 timeframe to reduce emissions and ensure robust in-use compliance.[42] Although much of the discussion focuses on the current state of the technology, the planned NPRM analysis necessarily will be based on our projections of future technology development and availability in accordance with the Clean Air Act.

The discussions below primarily concern the feasibility and effectiveness of the technologies. We request comment on each of the technologies discussed. Commenters are encouraged to address all aspects of these technologies including: costs, emission reduction effectiveness, impact on fuel consumption/CO_2 emissions, market acceptance factors, reliability, and the feasibility of the technology being available for widespread adoption in the 2027 and later timeframe. We also welcome comments on other technologies not discussed here. Finally, to the extent emission reductions will be limited by the manufacturers' engineering resources, we encourage commenters to address how we should prioritize or phase-in different requirements.

1. Diesel Engine Technologies Under Consideration

[41] U.S. Environmental Protection Agency. "Clean Diesel and DERA Funding" Available online: https://www.epa.gov/cleandiesel (accessed December 12, 2019)

[42] Although we are targeting model year 2027 for new standards, our technology evaluations are considering a broader timeframe to be more comprehensive.

The following discussion introduces the technologies and emission reduction strategies we are considering for the CTI, including thermal management technologies that can be used to better achieve and maintain adequate catalyst temperatures, and next generation catalyst configurations and formulations to improve catalyst performance across a broader range of engine operating conditions. Where possible, we note the technologies and strategies we are evaluating in our diesel technology feasibility demonstration program at EPA's National Vehicle and Fuels Emissions Laboratory. A description of additional technologies we are following is available in the docket.[43] From a regulatory perspective, EPA's evaluation of the effectiveness of technologies includes their emission reduction potential, as well as their durability over the engine's regulatory useful life and potential impact on CO_2 emissions.

The costs associated with the technologies in our demonstration program will also be considered, along with other relevant factors, in the overall feasibility analysis presented in the NPRM. Our assessment of costs is currently underway and will be an important component of the NPRM. Our current understanding of likely technology costs is based largely on survey data, catalyst costs published by the International Council for Clean Transportation (ICCT),[44] and catalyst volume and other emission component characteristics that engine manufacturers have submitted to EPA and claimed to be CBI. We have initiated a cost study based on a technology teardown approach that will apply the peer-reviewed methodology previously used for light-duty

[43] Mikulin, John. "Opposed-Piston Diesel Engines" Memorandum to Docket EPA-HQ-OAR-2019-0055. November 20, 2019

[44] Dallmann, T., Posada, F., Bandivadekar, A. "Costs of Emission Reduction Technologies for Diesel Engines Used in Non-Road Vehicles and Equipment" International Council on Clean Transportation. July 11, 2018. Available online: https://theicct.org/sites/default/files/publications/Non_Road_Emission_Control_20180711.pdf

vehicles.[45] This teardown analysis may still be underway during the planned timeline for the NPRM. We welcome comment including any available data on the cost, effectiveness, and limitations of the SCR and other emission control systems considered. We also request comment, including any available data, regarding the technical feasibility and cost of commercializing emerging technologies expected to enter the heavy-duty market by model year 2027.

Modern diesel engines rely heavily upon catalytic aftertreatment to meet emission standards – oxidation catalysts reduce hydrocarbons (HC) and carbon monoxide (CO), DPFs reduce PM, and SCR catalysts reduce NOx. Current designs typically include the diesel oxidation catalyst (DOC) function as part of the broader DPF/SCR system.[46] While DPFs remain effective at controlling PM during all types of operation[47], SCR systems (including the DOC function) are effective only when the exhaust temperature is sufficiently high. All three types of aftertreatment have the potential to lose effectiveness if the catalysts degrade. Potential technological solutions to these issues are discussed below, with a focus on the SCR system.

SCR works by injecting into the exhaust a urea-water solution, which decomposes to form gaseous ammonia (NH_3). NH_3 is a strong reducing agent that reacts to convert NOx to N_2 and H_2O over a range of catalytic materials. The DOC, located upstream of the SCR, uses a platinum (Pt) and palladium (Pd) catalyst to oxidize a portion of the exhaust NO to NO_2.[48] This oxidation

[45] Kolwich, G., Steier, A., Kopinski, D., Nelson, B. et al., "Teardown-Based Cost Assessment for Use in Setting Greenhouse Gas Emissions Standards," SAE Int. J. Passeng. Cars - Mech. Syst. 5(2):1059-1072, 2012, https://doi.org/10.4271/2012-01-1343.

[46] McDonald, Joseph. "Diesel Exhaust Emission Control Systems," Memorandum to Docket EPA-HQ-OAR-2019-0055. November 13, 2019.

[47] PM emissions can increase briefly during active regeneration of the DPF; however, such events are infrequent.

[48] The DOC also synergistically converts additional NO to NO_2, promoting low-temperature soot oxidation over the DPF.

facilitates the “fast” SCR reaction pathway that improves the SCR’s NOx reduction kinetics when exhaust temperatures are below 250°C and is highly-efficient above 250°C. An ammonia slip catalyst (ASC) is typically used immediately downstream of the SCR to prevent emissions of unreacted NH_3 into the environment.

Compression-ignition engine exhaust temperatures are low during cold starts, sustained idle, or low vehicle speed and light load. This impacts emissions because urea decomposition to NH_3 and subsequent NOx reduction over the SCR catalyst significantly decreases at exhaust temperatures of less than 190°C. Thus, technologies that accelerate warm-up from a cold start, and maintain catalyst temperature above 200 °C can help achieve further NOx reduction from SCR systems under those conditions. Technologies that improve urea decomposition to NH_3 at temperatures below 200 °C can also be used to reduce NOx emissions under cold start, light load, and low speed conditions. Additional discussion of is available in the docket.[49]

i. Advanced Catalyst Formulations

Catalysts continue to evolve as engine manufacturers demand formulations that are optimized for their specific performance requirements. Improvements to DOC and DPF washcoat[50] materials that increase active surface area and stabilize active materials have allowed a reduction in content of platinum group metals and a reduction in DOC size between MY2010 and MY2019. Increased usage of silicon carbide as DPF substrate material has allowed the use of

[49] McDonald, Joseph. “Diesel Exhaust Emission Control Systems,” Memorandum to Docket EPA-HQ-OAR-2019-0055. November 13, 2019.

[50] The wash-coat is a high surface area catalytic coating that is applied to a noncatalytic substrate. The wash-coat includes the active catalytic sites.

smaller DPF substrates that reduce exhaust backpressure and improve system packaging onto the vehicle.

Copper (Cu) exchanged zeolites have demonstrated hydrothermal stability, good low temperature performance, and represent a large fraction of the transition-metal zeolite SCR catalysts used in heavy-duty applications since 2010.[51] Improvements to both the coating processes and the substrates onto which the zeolites are coated have improved the low-temperature and high-temperature NOx conversion, improved selectivity of NOx reduction to N_2 (i.e., reduced selectivity to N_2O), and improved the hydrothermal stability. Improvements in SCR catalyst coatings over the past decade have included:[52,53,54,55,56]

- Optimization of Silicon/Aluminum (Al) and Cu/Al ratios
- Increased Cu content and Cu surface area
- Optimization of the relative positioning of Cu^{2+} ions within the zeolite structure
- The introduction of specific co-cations
- Co-exchanging of more than one type of metal ion into the zeolite structure

[51] Lambert, C.K. "Perspective on SCR NOx control for diesel vehicles." Reaction Chemistry & Engineering, 2019, 4, 969.
[52] Fan, C., et al. (2018). "The influence of Si/Al ratio on the catalytic property and hydrothermal stability of Cu-SSZ-13 catalysts for NH3-SCR." Applied Catalysis A: General 550: 256-265.
[53] Fedyko, J. M. and H.-Y. Chen (2015). Zeolite Catalyst Containing Metals. U. S. Patent No. US20150078989A1, Johnson Matthey Public Limited Company, London.
[54] Cui, Y., et al. (2020). "Influences of Na+ co-cation on the structure and performance of Cu/SSZ-13 selective catalytic reduction catalysts." Catalysis Today 339: 233-240.
[55] Fedyko, J. M. and H.-Y. Chen (2019). Zeolite Catalyst Coating Containing Metals. U. S. Patent No. US 20190224657A1, Johnson Matthey Public Limited Company, London, UK.
[56] Wang, A., et al. (2019). "NH3-SCR on Cu, Fe and Cu+ Fe exchanged beta and SSZ-13 catalysts: Hydrothermal aging and propylene poisoning effects." Catalysis Today 320: 91-99.

In the absence of more stringent NOx standards, these improvements have been realized primarily as reductions in SCR system volume, reductions in system cost, and improvements in durability since the initial introduction of metal-exchanged zeolite SCR in MY2010. We request comment on the extent to which advanced catalyst formulations can be used to lower emissions further, and whether they would have any potential impact on CO_2 emissions.

ii. Passive Thermal Management

Passive thermal management involves modifying components to increase and maintain the exhaust gas temperatures without active management. It is done primarily through insulation of the exhaust system and/or reducing its thermal mass (so it requires less exhaust energy to reach the light-off temperature).[57] Passive thermal management strategies generally have little to no impact on CO_2 emissions. The use of passive exhaust thermal management strategies in light-duty gasoline applications has led to significant improvements in emission performance. Some of these improvements could be applied to SCR systems used in heavy-duty applications as well.

Reducing the mass of the exhaust system and insulating between the turbocharger outlet and the inlet of the SCR system would reduce the amount of thermal energy lost through the walls. Moving the SCR catalyst nearer to the turbocharger outlet effectively reduces the available mass prior to the SCR inlet, minimizing heat loss and reducing the amount of energy needed to warm components up to normal operating temperatures. Using a smaller sized initial SCR with a lower density substrate reduces its mass and reduces catalyst warmup time. Dual-walled manifolds and

[57] Hamedi, M., Tsolakis, A., and Herreros, J., "Thermal Performance of Diesel Aftertreatment: Material and Insulation CFD Analysis," SAE Technical Paper 2014-01-2818, 2014, doi:10.4271/2014-01-2818.

exhaust pipes utilizing a thin inner wall and an air gap separating the inner and outer wall may be used to insulate the exhaust system and reduce the thermal mass, minimizing heat lost to the walls and decreasing the time necessary to reach operational temperatures after a cold start. Mechanical insulation applied to the exterior of exhaust components, including exhaust catalysts, is readily available and can minimize heat loss to the environment and help retain heat within the catalyst as operation transitions to lighter loads and lower exhaust temperatures. Integrating the DOC, DPF, and SCR substrates into a single exhaust assembly can also assist with retaining heat energy.

EPA is evaluating several passive thermal management strategies in the diesel technology feasibility demonstration program, including a light-off SCR located closer to the exhaust turbine (see Section III.A.1.v), use of an air-gap exhaust manifold and downpipe, and use of an insulated and integrated single-box system for the DOC, DPF, and downstream SCR/ASC. We will evaluate their combined ability to reduce the time to reach light-off temperature and achieve higher exhaust temperatures that should contribute to NOx reductions during low-load operation. We welcome comment on the current adoption of passive thermal management strategies, including any available data on the cost, effectiveness, and limitations.

iii. Active thermal management

Active thermal management involves using the engine and associated hardware to maintain and/or increase exhaust temperatures. This can be accomplished through a variety of means, including engine throttling, heated aftertreatment systems, and flow bypass systems.

Combustion phasing can also be used for thermal management and is discussed in the following section.

Diesel engines operate at very low fuel-air ratios (i.e., with considerable excess air) at light-load conditions. This causes relatively cool exhaust to flow through the exhaust system at low loads, which cools the catalyst substrates. This is particularly true at idle. It is also significant at moderate-to-high engine speeds with little or no engine power, such as when a vehicle is coasting down a hill. Air flow through the engine can be reduced by induction and/or exhaust throttling. All heavy-duty diesel engines are equipped with an electronic throttle control (ETC) within the induction system and most are equipped with a variable-geometry-turbine (VGT) turbocharger, and these systems can be used to throttle the induction and exhaust system, respectively, at light-load conditions. However, throttling reduces volumetric efficiency, and thus has a trade-off relative to CO_2 emissions.

Heat can be added to the exhaust and aftertreatment systems by burning fuel in the exhaust system or by using electrical heating (both of which can increase the SCR efficiency). Burner systems use an additional diesel fuel injector in the exhaust to combust fuel and create additional heat energy in the exhaust system. Electrically heated catalysts use electric current applied to a metal foil monolithic structure in the exhaust to add heat to the exhaust system. In addition, heated higher-pressure urea dosing systems improve the decomposition of urea at low exhaust temperatures and thus allow urea injection to occur at lower exhaust temperature (i.e., at less than 180° C). At light-load conditions with relatively high flow/low temperature exhaust, considerable fuel energy or electric energy would be needed for these systems. This would likely cause a considerable increase in CO_2 emissions with conventional designs.

Exhaust flow bypass systems can be used to manage the cooling of exhaust during cold start and low load operating conditions. For example, significant heat loss occurs as the exhaust gases flow through the turbocharger turbine. Turbine bypass valves allow exhaust gas to bypass the turbine and avoid this heat loss at low loads when turbocharging requirements are low. In addition, an EGR flow bypass valve would allow exhaust gases to bypass the EGR cooler when it is not required.

We welcome comment on active thermal management strategies, including any available data on the cost, effectiveness, and limitations, as well as information about its projected use for the 2024 to 2030 timeframe.

iv. Variable Valve Actuation (VVA)

Both gasoline and diesel engines control the flow of air and exhaust into and out of the engine by opening and closing camshaft-actuated intake and exhaust valves at specific times during the combustion cycle. VVA includes a family of valvetrain designs that alter the timing and/or lift of the intake valve, exhaust valve. These adjustments can reduce pumping losses, increase specific power, and control the level of residual gases in the cylinder. They can also reduce NOx emissions as discussed below.

VVA has been adopted in light-duty vehicles to increase an engine’s efficiency and specific power. It has also been used as a thermal management technology to open exhaust valves early to increase heat rejection to the exhaust and heat up exhaust catalysts more quickly. The same early exhaust valve opening (EEVO) has been applied to the Detroit DD8[58] to aid in DPF regeneration, but a challenge with this strategy for maintaining aftertreatment temperature is that it reduces cycle thermal efficiency, and thus can contribute to increased CO_2 emissions.

During low-load operation of diesel engines, exhaust temperatures can drop below the targeted catalyst temperatures and the exhaust flow can thus cause catalyst cooling. Cylinder deactivation (CDA), late intake valve closing (LIVC), and early intake valve closing (EIVC) are three VVA strategies that can also be used to reduce airflow through the exhaust system at light-load conditions, and have been shown to reduce the CO_2 emissions trade-off compared to use of the ETC and/or VGT for throttling.[59, 60]

Since we are particularly concerned with catalyst performance at low loads, EPA is evaluating two valvetrain-targeted thermal management strategies that reduce airflow at light-load conditions (i.e., less than 3-4 bar BMEP): CDA and LIVC. Both strategies force engines to operate at a higher fuel-air ratio in the active cylinders, which increases exhaust temperatures, with the benefit of little or no CO_2 emission increase and with potential for CO_2 emission decreases under some operating conditions. The key difference between these two strategies is that CDA completely removes airflow from a few cylinders with the potential for exhaust

[58] Detroit. "DETROIT DD8" Available online: https://demanddetroit.com/engines/dd8/

[59] Ding, C., Roberts, L., Fain, D., Ramesh, A.K., Shaver, G.M., McCarthy, J., et al.(2015). "Fuel efficient exhaust thermal management for compression ignition engines via cylinder deactivation and flexible valve actuation." Int.J.Eng. Res. doi:10.1177/1468087415597413.

[60] Neely, G.D., Sharp, C.A., Pieczko, M.S., McCarthy, J.E. (2019). "Simultaneous NO_X and CO_2 Reduction for Meeting Future CARB Standards Using a Heavy Duty Diesel CDA NVH Strategy." SAE International Journal of Engines, Paper No. JENG-2019-0075

temperature increases of up to 60^{o} C at light loads, while LIVC reduces airflow from all cylinders with up to 40^{o} C hotter exhaust temperatures.

We recognize that one of the challenges of CDA is that it requires proper integration with the rest of the vehicle's driveline. This can be difficult in the vocational vehicle segment where the engine is often sold by the engine manufacturer (to a chassis manufacturer or body builder) without knowing the type of transmission or axle used in the vehicle or the precise duty cycle of the vehicle. The use of CDA requires fine tuning of the calibration as the engine moves into and out of deactivation mode to achieve acceptable noise, vibration, and harshness (NVH). Additionally, CDA could be difficult to apply to vehicles with a manual transmission because it requires careful gear change control.

We are in the process of evaluating CDA as part of our feasibility demonstration. In addition to laboratory demonstrations of CDA's emission reduction potential, we are evaluating the cost to develop, integrate, and calibrate the hardware. We plan to evaluate both dynamic CDA with individual cylinder control that requires fully-variable valve actuation hardware, and fixed CDA that can be achieved by much simpler valve deactivation hardware commonly used in exhaust braking technology. The relatively simple fixed CDA system would be lower cost and we expect it would apply to a smaller range of operation with less potential for CO_2 benefits.

We believe that LIVC may provide emission reductions similar to fixed CDA with the added benefits of no NVH concerns and that a production-level system could be cost-competitive to

CDA. Thus, we will continue to evaluate it as a potential technological alternative to CDA.[61] We welcome comment on CDA and LIVC strategies for NOx reduction, including any available data on the cost, effectiveness, and technology limitations.

v. Dual-SCR Catalyst System

Another NOx reduction strategy we are evaluating is an alternative aftertreatment configuration known as a light-off or dual SCR system, which is a variation of passive thermal management. This system maintains a layout similar to the conventional SCR configuration discussed earlier, but integrates an additional small-volume SCR catalyst, close-coupled to the turbocharger's exhaust turbine outlet (Figure 1). This small SCR catalyst could be configured with or without an upstream DOC.

The benefits of this design result from its ability to warm up faster as a result of being closer to the engine. Such upstream SCR catalysts are also designed to have smaller substrates with lower density, both of which reduce the thermal inertia and allow them to warm up even faster. The upstream system would reach a temperature where urea injection could very soon after engine startup, followed quickly by catalyst light-off. These designs also require less input of heat energy into the exhaust to maintain exhaust temperatures during light-load operation. The urea injection to the close-coupled, light-off SCR can also be terminated once the second, downstream SCR reaches operational temperature, thus allowing additional NOx to reach the DOC and DPF to promote passive regeneration (soot oxidation) on the DPF.

[61] McDonald, Joseph. "Engine Modeling of LIVC for Heavy-duty Diesel Exhaust Thermal Management at Light-load Conditions" Memorandum to Docket EPA-HQ-OAR-2019-0055. November 21, 2019.

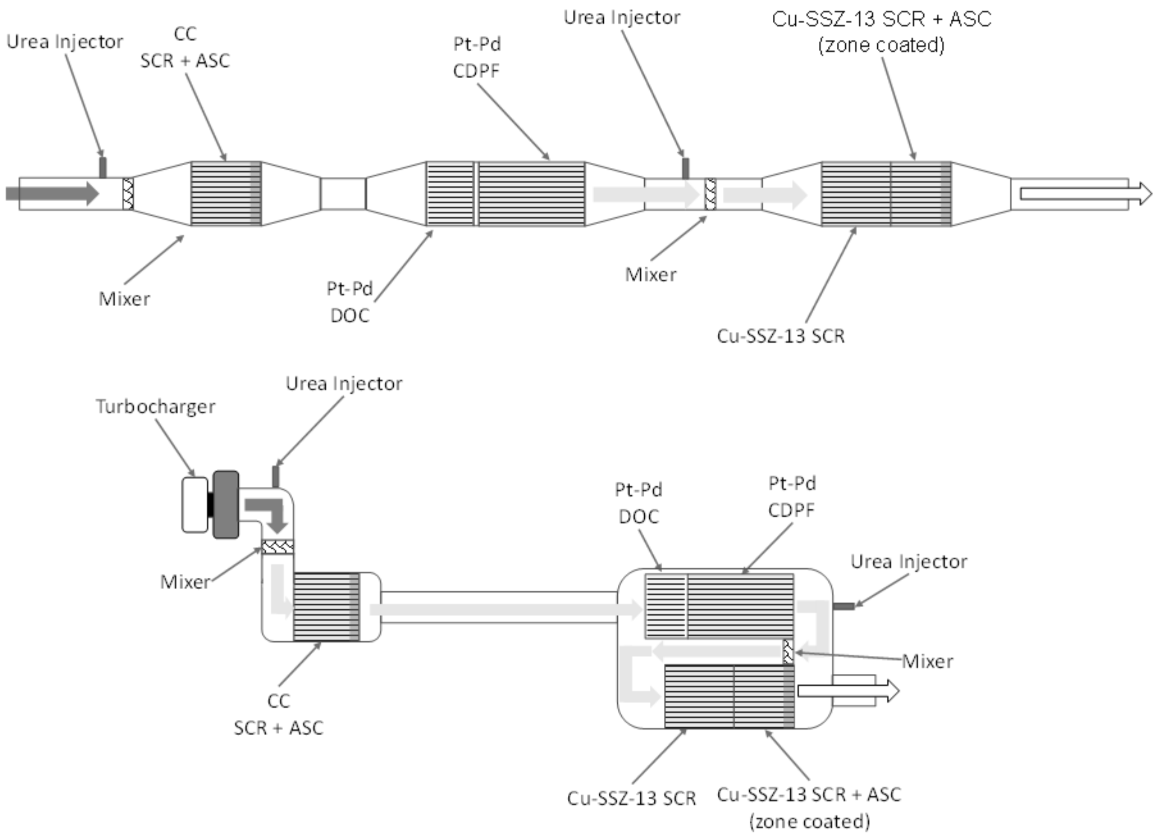

Figure 1: Potential layout of a 2027+ dual-SCR system in an in-line configuration (top) and comparable components integrated to improve passive thermal management (bottom).

EPA is evaluating this dual-SCR catalyst system technology as part of our diesel technology feasibility demonstration program. One concern that has been raised about this technology is the durability challenge associated with placing an SCR catalyst upstream of the DPF. To address this concern, a dual-SCR system is currently being aged at SwRI to an equivalent of 850,000 miles to better understand the impacts of catalyst degradation at much longer in-use operation than captured by today's regulatory useful life. We are utilizing an accelerated aging process[62] to thermally and chemically age the catalyst and will test catalyst performance at established checkpoints to measure the emission reduction performance as a function of miles. We plan to test this dual-SCR system individually as well as in combination with the thermal management strategies described in this section.

One of the design constraints that will be explored with EPA's evaluation of advanced SCR technology is nitrous oxide (N_2O) emissions. N_2O emissions are affected by the temperature of the SCR catalyst, SCR catalyst formulation, diesel exhaust fluid dosing rates and the makeup of NO and NO_2 upstream of the SCR catalyst. Limiting N_2O emissions is important because N_2O is a greenhouse gas and because highway heavy-duty engines are subject to the 0.10 g/hp-hr standard set in HD GHG Phase 1 rule.

vi. Aftertreatment Durability

The aging mechanisms of diesel exhaust aftertreatment systems are complex and include both chemical and hydrothermal changes. Aging mechanisms on a single component can also cascade into impacts on multiple catalysts and catalytic reactions within the system. Some aging impacts are fully reversible (i.e., the degradation can be undone under certain conditions). Other aging impacts are only partially reversible, irreversible, or can only be reversed with some form of intervention (e.g., changes to engine calibration to alter exhaust temperature and/or

[62] See Section III.F.4 for a description of the accelerated aging process used.

composition). A docket memo entitled "Diesel Exhaust Emission Control Systems" provides a more detailed summary of hydrothermal and chemical aging of diesel exhaust catalysts.[63]

Our holistic approach in CTI includes a reevaluation of current useful life values (see Section III.D), which could necessitate further improvements to prevent the loss of aftertreatment function at higher mileages. These potential improvements fall into the following categories:

- Designing excess capacity into the catalyst (e.g., increased catalyst volume, increased catalyst cell density, increased surface area for active materials in washcoating) so physical or chemical degradation of the catalyst does not reduce its performance
- Continued improvements to catalyst materials (such as the washcoat and substrate) to make them more durable (see more detailed discussion in section III.A.1.i)
    - Use of additives and other improvements specifically to prevent thermal or chemical breakdown of the zeolite structure within SCR coatings
    - Use of washcoat additives and other improvements to increase PGM dispersion, reduce PGM particle size, reduce PGM mobility and reduce agglomeration within the DOC and DPF washcoatings
- Direct fuel dosing downstream of the light-off SCR during active DPF regeneration to reduce exposure of the light-off SCR to fuel compounds and contaminants
- Improvements to catalyst housings and substrate matting material to minimize vibration and prevent leaks of exhaust gas

[63] McDonald, Joseph. "Diesel Exhaust Emission Control Systems" Memorandum to Docket EPA-HQ-OAR-2019-0055. November 13, 2019.

- Adjusting engine calibration and emissions control system design to minimize operation that would damage the catalyst (e.g., improved control of DPF active regeneration, increased passive DPF regeneration, fuel dosing downstream of initial light-off SCR)
- Use of specific engine calibration strategies to remove sulfur compounds from the SCR system
- Use of exhaust system designs that facilitate periodic DPF ash maintenance
- Diagnosis and prevention of upstream engine malfunctions that can potentially damage exhaust aftertreatment components

Increased SCR catalyst capacity with incrementally improved zeolite coatings would be the primary strategies for improving NOx control for a longer useful life. SCR capacity can be increased by approximately one-third through the use of a light-off SCR substrate combined with a downstream substrate with a volume roughly equivalent to the average volume of today's systems and with moderately increased catalytic activity due to continued incremental improvements to chabazite and other zeolite coatings used for SCR. Total SCR volume would thus increase by approximately one-third relative to today's systems. SCR capacity can also be increased in the downstream SCR system through the use of thin-wall (4 to 4.5 mil), high cell density (600 cells-per-square-inch) substrates.

Chemical aging of the DOC, DPF, and SCR can be reduced by the presence of an upstream light-off SCR. Transport and adsorption of S, P, Ca, Zn, Mg, Na, and K compounds and other catalyst poisons are more severe for the initial catalyst within an emissions control system and tend to reduce in severity for catalysts positioned further downstream. Further evolutionary improvements to the DOC washcoating materials to increase PGM dispersion and reduce PGM mobility and agglomeration would be anticipated for meeting increased useful life requirements.

The primary strategy for maintaining DPF function to a longer useful life would be through design of integrated systems that facilitate easier removal of the DPF for ash cleaning at regular maintenance intervals. Accommodation of DPF removal for ash maintenance is already incorporated into existing diesel exhaust system designs.[64] Improvements to catalyst housings and substrate matting material could be expected for all catalyst substrates within the system. Integration into a box-muffler type system could also be expected within the 2027 timeframe for all catalyst components (except for the initial close-coupled SCR) in order to improve passive thermal management.

vii. Closed Crankcases

During combustion, gases can leak past the piston rings sealing the cylinder and into the crankcase. These gases are called blowby gases and generally include unburned fuel and other combustion products. Blowby gases that escape from the crankcase are considered crankcase emissions.[65] Current regulations restrict the discharge of crankcase emissions directly into the ambient air, and blowby gases from gasoline engine crankcases have been controlled for many years by sealing the crankcase and routing the gases into the intake air through a positive crankcase ventilation (PCV) valve. However, there have been concerns about applying a similar technology for diesel engines. For example, high PM emissions venting into the intake system

[64] Eberspacher. "1BOX Product Literature"
[65] 40 CFR 86.402-78.

could foul turbocharger compressors. As a result of this concern, diesel-fueled and other compression-ignition engines equipped with turbochargers (or other equipment) were not required to have sealed crankcases.[66] For these engines, manufacturers are allowed to vent the crankcase emissions to ambient air as long as they are measured and added to the exhaust emissions during all emission testing.

Because all new highway heavy-duty diesel engines on the market today are equipped with turbochargers, they are not required to have closed crankcases under the current regulations. Manufacturer compliance data indicate a portion of current highway heavy-duty diesel engines have closed crankcases, which suggests that some heavy-duty engine manufacturers have developed systems for controlling crankcase emissions that do not negatively impact the turbocharger. EPA is considering provisions to require a closed crankcase ventilation system for all highway compression-ignition engines to prevent crankcase emissions from being emitted directly to the atmosphere. These emissions could be routed upstream of the aftertreatment system or back into the intake system. Our reasons for considering this requirement are twofold.

While the exception in the current regulations for certain compression-ignition engines requires manufacturers to quantify their engines' crankcase emissions during certification, they report non-methane hydrocarbons in lieu of total hydrocarbons. As a result, methane emissions from the crankcase are not quantified. Methane emissions from diesel-fueled engines are generally low; however, they are a concern for compression-ignition-certified natural gas-fueled heavy-duty engines because the blowby gases from these engines have a higher potential to

[66] 40 CFR 86.007-11(c).

include methane emissions. EPA proposed to require that all natural gas-fueled engines have closed crankcases in the Heavy-Duty Phase 2 GHG rulemaking, but opted to wait to finalize any updates to regulations in a future rulemaking (81 FR at 73571, October 25, 2016).

In addition to our concern of unquantified methane emissions, we believe another benefit to closed crankcases would be better in-use durability. We know that the performance of piston seals reduces as the engine ages, which would allow more blowby gases and could increase crankcase emissions. While crankcase emissions are included in the durability tests that estimate an engine's deterioration, those tests were not designed to capture the deterioration of the crankcase. These unquantified age impacts continue throughout the operational life of the engine. Closing crankcases could be a means to ensure those emissions are addressed long-term to the same extent as other exhaust emissions.

EPA is conducting emissions testing of open crankcase systems and will be developing the technology costs associated with a closed crankcase ventilation system. We request comment, including any available data, on the appropriateness and costs of requiring closed crankcases for all heavy-duty compression-ignited engines.

viii. Fuel Quality

EPA has long recognized the importance of fuel quality on motor vehicle emissions and has regulated fuel quality to enable compliance with emission standards. In 1993 EPA limited diesel sulfur content to a maximum of 500 ppm and put into place a minimum cetane index of 40. Starting in 2006 with the establishment of more stringent heavy-duty highway PM, NOx, and HC emission standards, EPA phased-in a 15-ppm maximum diesel fuel sulfur standard to enable heavy-duty diesel truck compliance with the more stringent emission standards.

Recently an engine manufacturer raised concerns to EPA regarding the metal content of highway diesel fuel.[67] The engine manufacturer observed higher than normal concentrations of alkali and alkaline earth metals (i.e., Na, K, Ca, and Mg) in its highway diesel fuel samples. These metals can lead to fouling of the aftertreatment control systems and an associated increase in emissions. The engine manufacturer claims that biodiesel is the source of the high metal content in diesel fuel, and that higher biodiesel blends, such as B20, are the principal problem. The engine manufacturer states that the engine's warranty will be voided if biodiesel blends greater than 5 percent (B5) are used.

Over the last decade, biodiesel content in diesel fuel has increased under the Renewable Fuels Standard. In 2010, less than 400 million gallons of biodiesel were consumed, whereas in 2018, over 2 billion gallons of biodiesel were being blended into diesel fuel. While the average biodiesel content in diesel fuel was around 3.5 percent in 2018, biodiesel is being blended on per batch basis into highway diesel fuel at levels ranging from 0 to 20 volume percent.

EPA compared data collected by the National Renewable Energy Laboratory (NREL) on the metal content of biodiesel to that provided by the engine manufacturer. The NREL data showed fewer samples exceeding the maximum metals concentration limits contained in ASTM D6751-18, although in both cases the small sample sizes could be biasing the results.[68] Numerous

[67] Recker, Alissa, "Fuel Quality Impacts on Aftertreatment and Engine;" Daimler Trucks, July 29, 2019.
[68] Wyborny, Lester. "References Regarding Metals in Diesel and Biodiesel Fuels." Memorandum to Docket EPA-HQ-OAR-2019-0055. November 11, 2019

studies have collected and analyzed emission data from diesel engines operated on biodiesel blended diesel with controlled amounts of metal content.[69] Some of these studies show an impact on emissions, while others do not.

EPA has also heard concerns from some stakeholders that water in highway diesel fuel meeting the ASTM D975 water and sediment limit of 0.05 volume percent can cause premature failure of fuel injectors due to corrosion from the presence of dissolved alkali and alkaline earth metals.

EPA requests comment on concerns regarding metal and water contamination in highway diesel fuel and on the potential role of biodiesel in this contamination. EPA seeks data on the levels of these contaminants in fuels, including the prevalence of contamination, and on the associated degradation and failure of engines and aftertreatment function.

2. Gasoline Engine Technologies Under Consideration

Automobile manufacturers have made progress reducing NOx, CO and HC from gasoline-fueled passenger cars and light-duty trucks. Similar to the DOC and SCR catalysts described previously, three-way catalysts perform at a very high level once operating temperature is achieved. There is a short window of operation following a cold start when the exhaust temperature is low and the three-way catalyst has not reached light-off, resulting in a temporary spike in CO, HC, and NOx. A similar reduction in catalyst efficiency can occur due to sustained idle or creep-crawl operation that vehicles may experience in dense traffic if the catalyst configuration does not maintain temperatures above the light-off temperature. Gasoline engines

[69] *Id.*

generally operate near stoichiometric fuel-air ratios, creating optimal conditions for a three-way catalyst to simultaneously convert CO, NO, and HC to CO_2, N_2, and H_2O. However, as introduced in Section II.B.2, heavy-duty engine manufacturers often implement enrichment-based strategies for engine and catalyst protection at high load, which reduces the effectiveness of the three-way catalyst and increases emissions. The following section describes technologies we believe can address these emissions increases.

i. Technologies to Reduce Exhaust Emissions

As mentioned in Section II.B.2, most chassis-certified heavy-duty vehicles are subject to EPA's light-duty Tier 3 program and these vehicles have adopted many of the emissions technologies from their light-duty counterparts (79 FR 23414, April 28, 2014). To meet these Tier 3 emission standards, manufacturers have reduced the time for the catalyst to reach operational temperature by implementing cold-start strategies to reduce light-off time and moved the catalyst closer to the exhaust valve. Manufacturers have not widely adopted the same strategies for their engine-certified products. In particular, we believe there are opportunities to reduce cold-start and low-load emissions from engine-certified heavy-duty gasoline engines by adopting the following strategies to accelerate light-off and keep the catalyst warm:

- Close-couple the catalyst to the engine
- Improved catalyst material and loading
- Improved exhaust system insulation

Additionally, we believe material improvements to the catalyst, manifolds, and exhaust valves could increase their ability to withstand higher exhaust temperatures and would therefore reduce the need for enrichment-based protection modes that result in elevated emissions under high-load operation. Catalyst technology continues to advance to meet engine manufacturers' demand for earlier and sustained light-off for low-load emission control, as well as increased maximum temperature thresholds allowing catalysts to withstand close-coupling and elevated exhaust temperatures during high load.

Similar to EPA's diesel engine demonstration project, we are testing heavy-duty gasoline engines and technologies that are available today on a range of Class 3 to 7 vehicles. The three engines in this test program represent a majority of the heavy-duty gasoline market and include both engine- and chassis-certified configurations. Emissions performance of engine- and chassis-certified configurations are being evaluated using chassis-dynamometer and real-world portable emissions measurement system (PEMS) testing. Early testing showed significant differences in emissions performance between engine-certified and chassis-certified configurations (primarily as a result of differences in catalyst location).[70]

Moving the catalyst into a close-coupled configuration is one approach adopted for chassis-certified gasoline engines to warm-up and activate the catalyst during cold-start and light load operation. Close-coupled locations may increase the catalysts' exposure to high exhaust temperatures, especially for heavy-duty applications that operate frequently in high-load operation. However, this can be overcome by adopting improved catalyst materials or identifying an optimized, closer-coupled catalyst location that enhances warm-up without extended time at high temperatures. We welcome comment on other performance characteristics

[70] Mitchell, George, "EPA's Medium Heavy-Duty Gasoline Vehicle Emissions Investigation". February 2019.

of engine and aftertreatment technologies from chassis-certified vehicles when applied to engine-certified products, specifically placing the catalyst in a location more consistent with chassis-certified applications.

We also welcome comment on heavy-duty gasoline engine technology costs. We plan to develop our technology cost estimates for the NPRM based on information from light-duty and chassis-certified heavy-duty pick-up trucks and vans that are regulated under EPA's Tier 3 program.[71]

Finally, we believe there may be opportunity for further reductions in PM from heavy-duty gasoline engines. Gasoline PM forms under high-load, rich fuel-air operation and is more prevalent as engines age and parts wear. Strategies to reduce or eliminate fuel-air enrichment under high-load operation would reduce PM formation. In addition, gasoline particulate filters (GPF), which serve the same function as DPFs on diesel engines, may be an effective means of PM reduction for heavy-duty gasoline engines as well.[72] We request comment on the need for more stringent PM standards for heavy-duty gasoline engines.

ii. Technologies to Address Evaporative Emissions

As exhaust emissions from gasoline engines continue to decrease, evaporative emissions become an increasingly significant contribution to overall HC emissions from gasoline-fueled

[71] EPA. "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule Regulatory Impact Analysis" EPA-420-R-14-005, February 2014, available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100ISWM.PDF?Dockey=P100ISWM.PDF.

[72] Jiacheng Yang, Patrick Roth, Thomas D. Durbin, Kent C. Johnson, David R. Cocker, III, Akua Asa-Awuku, Rasto Brezny, Michael Geller, and Georgios Karavalakis (2018) "Gasoline Particulate Filters as an Effective Tool to Reduce Particulate and Polycyclic Aromatic Hydrocarbon Emissions from Gasoline Direct Injection (GDI) Vehicles: A Case Study with Two GDI Vehicles" Environmental Science & Technology doi: 10.1021/acs.est.7b05641.

vehicles. To evaluate the evaporative emission performance of current production heavy-duty gasoline vehicles, EPA tested two heavy-duty vehicles over running loss, hot soak, three-day diurnal, on-board refueling vapor recovery (ORVR) and static test procedures. These engine-certified “incomplete” vehicles meet the current heavy-duty evaporative running loss, hot soak, three-day diurnal emission requirements. However, as they are certified as incomplete vehicles, they are not required to control refueling emissions and do not have ORVR systems. Results from the refueling testing confirm that these vehicles have much higher refueling emissions than gasoline vehicles with ORVR controls.[73,74]

EPA is evaluating the opportunity to extend the usage of the refueling evaporative emission control technologies already implemented in complete heavy-duty gasoline vehicles to the engine-certified incomplete gasoline vehicles in the over-14,000 lb. GVWR category. The primary technology we are considering is the addition of ORVR, which was first introduced to the chassis-certified light-duty and heavy-duty applications beginning in MY 2000 (65 FR 6698, February 10, 2000). An ORVR system includes a carbon canister, which is an effective technology designed to capture HC emissions during refueling events when liquid gasoline displaces HC vapors present in the vehicle’s fuel tank as the tank is filled. Instead of releasing the HC vapors into the ambient air, ORVR systems recover these HC vapors and store them for later use as fuel to operate the engine.

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[73] SGS-Aurora, Eastern Research Group, “Light Heavy-Duty Gasoline Vehicle Evaporative Emissions Testing.” EPA-420-R-19-017. December 2019.

[74] U.S. Environmental Protection Agency. "Summary of “Light Heavy-Duty Gasoline Vehicle Evaporative Emissions Test Program”" EPA-420-S-19-002. December 2019.

The fuel systems on these over-14,000 pound GVWR incomplete heavy-duty gasoline vehicles are similar to complete heavy-duty vehicles that are already required to incorporate ORVR. These incomplete vehicles may have slightly larger fuel tanks than most chassis-certified (complete) heavy-duty gasoline vehicles and are somewhat more likely to have dual fuel tanks. These differences may require a greater ORVR system storage capacity and possibly some unique accommodations for dual tanks (e.g., separate fuel filler locations), but we expect they will maintain a similar design. We are aware that some engine-certified products for over-14,000 GVWR gasoline vehicles are sold as incomplete chassis without complete fuel systems. Thus, the engine-certifying entity currently may not know or be in control of the filler system location and integration limitations for the final vehicle body configuration. This dynamic has been addressed for other emission controls through a process called delegated assembly – where the certifying manufacturer delegates certain assembly obligations to a downstream manufacturer.[75]

We request comment on EPA expanding our ORVR requirements to incomplete heavy-duty vehicles. We are particularly interested in the challenges of multiple manufacturers to appropriately implement ORVR systems on the range of gasoline-fueled vehicle products in the market today. We also seek comment on refueling test procedures, including the appropriateness of engineering analysis to adapt existing test procedures that were developed for complete vehicles to apply for incomplete vehicles.

3. Emission Monitoring Technologies

[75] See 40 CFR 1068.260 and 1068.261.

As heavy-duty engine performance has become more sophisticated, the industry has developed increasingly advanced sensors on board the vehicle to monitor the performance of the engine and emission controls. For the CTI, we are particularly interested in recent developments in the performance of zirconia NOx sensors that manufacturers are currently using to measure NOx concentrations and control SCR urea dosing. EPA has identified applications where we believe the use of these and other onboard sensors could enhance and potentially streamline existing EPA programs. We discuss those applications in Section III.F.

We recognize that one of the challenges to relying on sensors for these applications is the availability of NOx sensors that are continuously operational and accurate at low concentration levels. As a result, we are beginning a study to assess the accuracy, repeatability, noise, interferences, and response time of current NOx sensors. However, we encourage commenters to submit information to help us project whether the state of NOx sensor technology in the 2027 timeframe would be sufficient to enable such programs. We also request comment on the durability of NOx sensors, as well as specific maintenance or operational strategies that could be considered to substantially extend the life of these components and any regulatory barriers to implementing these strategies.

In addition to the performance of onboard NOx sensors, we are following the industry's increasing adoption of telematics systems that could enable the manufacturer to communicate with the vehicle's onboard computer in real-time. We request comment on the prevalence of telematics, the range of information that can be shared over-the-air, and limitations of the technology today. As we describe in Section III.F.3, the combination of advanced onboard sensors and telecommunications could facilitate the ability to determine tailpipe NO_x emissions of the vehicle in-use to reduce compliance burden in the future. We also request comment on the potential for alternative communication approaches to be used. For example, for vehicles not equipped with telematics, would manufacturers still be able to collect data from the vehicle during service at their dealerships?

Finally, we request comment on whether and how improved communication systems could be leveraged by manufacturers or in state, local, or tribal government programs to promote emission reductions from the heavy-duty fleet.

4. Hybrid, Battery-Electric, and Fuel Cell Vehicles

Hybrid technologies that recover and store braking energy have been used extensively in light-duty applications as fuel saving features. They are also being adopted in certain heavy-duty applications, and their heavy-duty use is projected to increase significantly over the next several years as a result of the HD Phase 2 GHG standards. However, the HD Phase 2 rule also identified plug-in hybrid vehicles (where the battery can be charged from an external power source), battery-electric vehicles (where the vehicle has no engine), and fuel cell vehicles (where the power supply is not an internal combustion engine, or ICE) as more advanced technologies that were not projected to be adopted in the heavy-duty market without additional incentives (81 FR 73497, October 25, 2016).

Hybrid technologies range from mild hybrids that recover braking energy for accessory use (often using a supplemental 48V electrical battery), to fully-hybrid vehicles with integrated electric motors at the wheels capable of propelling the vehicle with the engine turned off; and their emissions impact varies by integration level and design. Existing heavy-duty hybrid technologies have the potential to decrease or increase NOx emissions, depending on how they are designed. For example, a hybrid system can reduce NOx emissions if it eliminates idle operation or uses the recovered electrical energy to heat aftertreatment components. In contrast, it can increase NOx emissions if it reduces the engine's ability to maintain sufficiently high aftertreatment temperatures during low-load operation.

Since battery-electric and hydrogen fuel cell vehicles do not have ICEs, they have zero tailpipe emissions of NOx. We request comment on whether, and if so how, the CTI should project use of these more advanced technologies as NOx reduction technologies. These technologies as well as the more conventional hybrid technologies are collectively referred to as advanced powertrain technologies for the remainder of this discussion.

We are focused on three objectives related to these advanced powertrain technologies in CTI:

1. To reflect market adoption of these technologies in the 2027 and beyond timeframe as accurately as possible in the baseline analysis (i.e., without reflecting potential responses from CTI requirements),
2. To address barriers to market adoption due to EPA emissions certification requirements
3. To understand whether and how any incentives may be appropriate given the substantial tailpipe emission reduction potential of these technologies.

The choice of which powertrain technology to select for a particular heavy-duty vehicle application depends on factors such as number of miles traveled per day, accessibility of refueling infrastructure (i.e., charging stations, hydrogen fuel cell refilling stations), and driver preferences (e.g., noise level associated with electric versus ICEs).To address the first focus area, we are currently conducting stakeholder outreach and reviewing published projections of advanced emissions technologies. Our initial review of information suggests that there are a wide range of advanced powertrain technologies available today, including limited production of more than 100 battery-electric or fuel cell vehicle models offering zero tailpipe emissions.[76] Looking forward, a variety of factors will influence the extent to which hybrid and zero emissions heavy-duty vehicles are available for purchase and enter the market.[77,78] Of these, the lifetime total cost of ownership (TCO), which includes maintenance and fuel costs, is likely a primary factor. Initial information suggests that TCO for light- and medium heavy-duty battery-electric vehicles could reach cost parity with diesel in the early 2020s, while heavy heavy-duty battery-electric or hydrogen vehicles are likely to reach cost parity with diesel closer to the 2030 timeframe.[79] The TCO for hybrid technologies, and its relation to diesel vehicles, will vary based on the specifics of the hybrid system (e.g., cost and benefits of a 48V battery versus an integrated electric motor).

[76] ICCT (2019) “Estimating the infrastructure needs and costs for the launch of zero-emissions trucks”; available online at: https://theicct.org/publications/zero-emission-truck-infrastructure.

[77] McKinsey (2017) “New reality: electric trucks and their implications on energy demand”; available online at: https://www.mckinsey.com/industries/oil-and-gas/our-insights/a-new-reality-electric-trucks

[78] NACFE (2018) Guidance Report: Electric Trucks – Where They Make Sense; available online at: https://nacfe.org/report-library/guidance-reports/ [79] ICCT (2019) “Estimating the infrastructure needs and costs for the launch of zero-emissions trucks”; available online at: https://theicct.org/publications/zero-emission-truck-infrastructure.

[79] ICCT (2019) “Estimating the infrastructure needs and costs for the launch of zero-emissions trucks”; available online at: https://theicct.org/publications/zero-emission-truck-infrastructure.

Beyond TCO, considerations such as noise levels, vehicle weight, payload capacity, operational range, charging/refueling time, safety, and other driver preferences may influence the rate of market entry.[80,81] State and local activities, such as the Advanced Clean Trucks rulemaking underway in California could also influence the market trajectory for battery-electric and fuel cell technologies.[82] EPA requests comment on the likely market trajectory for advanced powertrain technologies in the 2020 through 2045 timeframe. Commenters are encouraged to provide data supporting their perspectives on reasonable adoption rates EPA could use for hybrid, battery-electric, and fuel cell heavy-duty vehicles relative to the full heavy-duty vehicle fleet in specific time periods (e.g., early 2020s, late 2020s, 2030, 2040, 2050).

For addressing potential barriers to market, stakeholders previously expressed concern that the engine-focused certification process for criteria pollutant emissions does not provide a pathway for hybrid powertrains to demonstrate NOx reductions from hybrid operations during certification. As such, we plan to propose an update to our powertrain test procedure for hybrids, previously developed as part of the HD Phase 2 rulemaking for greenhouse gas emissions, so that it can be applied to criteria pollutant certification.[83,84] We are interested in whether a hybrid powertrain test procedure addresses concerns with certifying the full range of heavy-duty hybrid products, or if other options might be useful for specific products, such as mild hybrid systems.

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[80] McKinsey (2017) "New reality: electric trucks and their implications on energy demand"; available online at: https://www.mckinsey.com/industries/oil-and-gas/our-insights/a-new-reality-electric-trucks.

[81] NACFE (2018) Guidance Report: Electric Trucks – Where They Make Sense; available online at: https://nacfe.org/report-library/guidance-reports/.

[82] For more information on this proposed rulemaking in California see: https://ww2.arb.ca.gov/rulemaking/2019/advancedcleantrucks?utm_medium=email&utm_source=govdelivery.

[83] 40 CFR 1036.505.

[84] 40 CFR 1036.510.

If stakeholders view alternative options as useful, then we request input on what those options might include.

We are also aware that current OBD requirements necessitate close cooperation between engine and hybrid system manufacturers for certification, and the process has proven sufficiently burdensome such that few alliances have been pursued to-date. We are interested in better understanding this potential barrier to heavy-duty hybrid systems, and any potential opportunities EPA could consider to address it.

Finally, related to the area of incentives, we are exploring simple approaches, such as emission credits, targeted for specific market segments for which technology development may be more challenging (e.g., extended range battery-electric or fuel cell technologies). We request comment on any barriers or incentives that EPA could consider in order to better encourage emission reductions from these advanced powertrain technologies. Commenters are encouraged to provide information on the potential impacts of regulatory barriers or incentives for all the advanced powertrain technologies discussed here (hybrids, battery-electric, fuel cell), including the extent to which these technologies may lower NOx and other criteria pollutant emissions.

5. Alternative Fuels

In the case of alternative fuels, we have typically applied the gasoline- and diesel-fueled engine standards to the alternatively-fueled engines based on the combustion cycle of the alternatively-fueled engine: applying the gasoline-fueled standards to spark-ignition engines and the diesel-fueled standards to compression-ignition engines. This approach is often called "fuel neutral."

Most heavy-duty vehicles today are powered by diesel engines. These engines have been optimized over many years to be reliable, durable, and fuel efficient. Diesel fuel also has the advantage of being very stable and having a high energy density. Gasoline-fueled engines are the second-most popular choice, especially for light and medium heavy-duty vehicles. They tend to be lighter and less expensive than diesel engines although less durable and less fuel efficient. We do not expect a shift in the market between diesel and gasoline as a result of the CTI and we are requesting comment on the extent to which CTI could have such effects.

With relatively low natural gas prices (compared to their peak values) in recent years, the heavy-duty industry has become increasingly interested in engines that are fueled with natural gas. It has some emission advantages over diesel, with lower engine-out levels of both NOx and PM. Several heavy-duty CNG engines have been certified with NOx levels better than 90 percent below US 2010 standards. However, because natural gas must be distributed and stored under pressure, there are additional challenges to using it as a heavy-duty fuel. We request comment on how natural gas should be treated in the CTI, including the possible provision of incentives.

Dimethyl ether (DME) is a related alternative fuel that also shows some promise for compression-ignition engines. It can be readily synthesized from natural gas and can be stored at lower pressures. We request comment on the extent to which the CTI should consider DME.

LPG is also used in certain lower weight-class urban applications, such as airport shuttle buses, school buses, and emergency response vehicles. LPG use is not extensive, nor do we project it to grow significantly in the CTI timeframe. However, given its emission advantages over diesel, we request comment on how LPG should be treated in the CTI, particularly for vocational heavy-duty engines and vehicles.

B. Standards and Test Cycles

EPA emission standards have historically applied with respect to emissions measured while the engine or vehicle is operating over a specific duty cycle. The primary advantage of this approach is that it provides very repeatable emission measurements. In other words, the results should be the same no matter when or where the test is performed, as long as the specified test procedures are used. For heavy-duty, these tests are generally performed on the engine without the vehicle.

We continue to consider these pre-production upfront demonstrations as the cornerstone of ensuring in-use emission compliance. On the other hand, tying standards to specific test cycles opens the possibility of emission controls being designed more to the test procedures than to in-use operation. Since 2004, we have applied additional in-use standards for diesel engines that allow higher emission levels but are not limited to a specific duty cycle, and instead measure emissions over real-world, non-prescribed driving routes that cover a range of in-use operation.

In this section we describe the updates we are considering for our duty-cycle program. We do not include specific values, but welcome comments and data which will assist EPA in developing appropriate standards to propose that could apply to the updated procedures we present. We also welcome comments on the relative importance of laboratory-based test cycle standards and standards that can be evaluated with the whole vehicle.

1. Emission Standards for RMC and FTP Cycles

Heavy-duty engines are subject to brake-specific (g/hp-hr) standards for emissions of NOx, PM, NMHC, and CO. These standards must be met by all diesel engines over both the Federal Test Procedure (FTP) cycle and the Ramped-Modal Cycle (RMC). Gasoline engines are only subject to testing over an FTP cycle designed for spark-ignition engines. The FTP cycles, which date back to the 1970s, are composites of a cold-start and a hot-start transient duty cycle designed to represent urban driving. The cold-start emissions are weighted by one-seventh and the hot-start emissions are weighted by six-sevenths.[85] The RMC is a more recent cycle for diesel engines that is a continuous cycle with ramped transitions between the thirteen steady-state modes.[86] The RMC does not include engine starting and is intended to represent fully warmed-up operating modes not emphasized in the FTP, such as sustained high speeds and loads.

Based on available information, it is clear that application of the diesel technologies discussed in Sections III.A.1 should enable emission reductions of at least 50 percent compared to current standards over the FTP and RMC cycles.[87,88] Some estimates suggest that emission reductions of 90 percent may be achievable across the heavy-duty engine market by model year 2027. We

[85] See 40 CFR 86.007-11 and 40 CFR 86.08-10.

[86] See 40 CFR 1065.505.

[87] California Air Resources Board, "Staff White Paper: California Air Resources Board Staff Current Assessment of the Technical Feasibility of Lower NOx Standards and Associated Test Procedures for 2022 and Subsequent Model Year Medium-Duty and Heavy-Duty Diesel Engines". April 18, 2019. Available online: https://ww3.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf.

[88] Manufacturers of Emission Controls Association. "Technology Feasibility for Model Year 2024 Heavy-Duty Diesel Vehicles in Meeting Lower NOx Standards". June 2019. Available online: http://www.meca.org/resources/MECA_MY_2024_HD_Low_NOx_Report_061019.pdf.

request information that would help us determine the appropriate levels of any new emission standards for the FTP and RMC cycles.

We are considering changes to the weighting factors for the FTP cycle for heavy-duty engines. We have historically developed our test cycles and weighting factors to reflect real-world operation. However, we recognize both engine technology and in-use operation can change over time. The current FTP weighting of cold-start and hot-start emissions was adopted in 1980 (45 FR 4136, January 21, 1980). It reflects the overall ratio of cold and hot operation for heavy-duty engines generally and does not distinguish by engine size or intended use. Given the importance of this weighting factor, we request comment on the appropriateness of the current weighting factors across the engine categories.[89] We are also interested in comment on how to address any challenges manufacturers may encounter to implement changes to the weighting factors.

We have also observed an industry trend toward engine down-speeding – that is, designing engines to do more of their work at lower engine speeds where frictional losses are lower. To address this trend for EPA's CO_2 standards testing, we adopted new RMC weighting factors for CO_2 emissions in the Phase 2 final rule (81 FR 73550, October 25, 2016). Since we believe these new weighting factors better reflect in-use operation of current and future heavy-duty engines, we request comment on applying these new weighting factors for NOx and other criteria pollutants as well.

[89] For instance, cold-start operation for line-haul tractors may represent significantly less than 1/7 of their total in-use operation, yet cold-start operation may represent a higher fraction of operation for other vocational vehicles.

2. New Emission Test Cycles and Standards

Review of in-use data has indicated that SCR-based emission controls systems for diesel engines are not functional over a significant fraction of real-world operation due to low aftertreatment temperatures, which are often the result of extended time at low load and idle operation.[90,91,92] Our current in-use testing procedures (described in Section III.C) were not designed to capture this type of operation. Test data collected as part of EPA's manufacturer-run in-use testing program indicate that low-load operation could account for more than half of the NO_X emissions from a vehicle over a given shift-day.[93]

EPA is considering the addition of a low-load test cycle and standard that would require diesel engine manufacturers to maintain the emission control system's functionality during operation where the catalyst temperatures have historically been below their operational temperature. The addition of a low-load duty-cycle could complement the expanded operational coverage of in-use testing requirements we are also considering. We have been following CARB's low-load cycle development in "Stage 2" of their Low NOx Demonstration program. SwRI and NREL developed several candidate cycles with average power and duration characteristics intended to test today's diesel engine emission controls under three low-load operating conditions: transition

[90] Hamady, Fakhri, Duncan, Alan. "A Comprehensive Study of Manufacturers In-Use Testing Data Collected from Heavy-Duty Diesel Engines Using Portable Emissions Measurement System (PEMS)". 29th CRC Real World Emissions Workshop, March 10 -13, 2019.

[91] Sandhu, Gurdas, et al. "Identifying Areas of High NOx Operation in Heavy-Duty Vehicles". 28th CRC Real-World Emissions Workshop, March 18-21, 2018.

[92] Sandhu, Gurdas, et al. "In-Use Emission Rates for MY 2010+ Heavy-Duty Diesel Vehicles". 27th CRC Real-World Emissions Workshop, March 26-29, 2017.

[93] Sandhu, Gurdas, et al. "Identifying Areas of High NOx Operation in Heavy-Duty Vehicles". 28th CRC Real-World Emissions Workshop, March 18-21, 2018.

from high- to low-load, sustained low-load, and transition from low- to high-load.[94] In September 2019, CARB selected the 90-minute "LLC Candidate #7" as the final cycle they are considering for their Low NOx Demonstration program.[95] EPA requests comment on the addition of a low-load cycle, the appropriateness of CARB's Candidate #7 low-load cycle, or other engine operation a low-load cycle should encompass, if adopted.

In addition to adding a low-load cycle, CARB currently has an idle test procedure and accompanying standard of 30 g/h for diesel engines to be "Clean Idle Certified".[96] We request comment on the need or appropriateness of setting a federal idle standard for diesel engines.

As mentioned previously, heavy-duty gasoline engines are currently subject to FTP testing, but not RMC testing. We request comment on including additional test cycles that may encourage manufacturers to improve the emissions performance of their heavy-duty gasoline engines in operating conditions not covered by the FTP cycle. In particular, we are considering proposing an RMC procedure to include the sustained high speeds and high loads that often produce high HC and PM emissions. We may also propose a low-load or idle cycle to address high CO from gasoline engines under those conditions. CARB's low-load cycle was designed to assess diesel engine aftertreatment systems under low-load operation. We request comment on the need for a low-load or idle cycle in general, and suitability of CARB's diesel-targeted low-

[94] California Air Resources Board. "Heavy-Duty Low NOx Program Public Workshop: Low Load Cycle Development". Sacramento, CA. January 23, 2019. Available online: https://ww3.arb.ca.gov/msprog/hdlownox/files/workgroup_20190123/02-llc_ws01232019-1.pdf.

[95] California Air Resources Board. "Heavy-Duty Low NOx Program: Low Load Cycle" Public Workshop. Diamond Bar, CA. September 26, 2019. Available online: https://ww3.arb.ca.gov/msprog/hdlownox/files/workgroup_20190926/staff/03_llc.pdf.

[96] 13 CCR § 1956.8 (6)(C) – Optional NOx idling emission standard.

load and clean idle cycles for evaluating the emissions performance of heavy-duty gasoline engines as well.

In addition to proposing changes to the test cycles, we are considering updates to the engine mapping test procedure for heavy-duty gasoline engines. The current test procedure, which is the same for all engine sizes, is intended to generate a "torque curve" that represents the peak torque at any specific engine speed point.[97] Historically, that goal was easily achieved due to the simplicity of the heavy-duty gasoline engine hardware and controls. Modern heavy-duty gasoline engines are more complex, with interactive features such as spark advance, fuel-air ratio, and variable valve timing that temporarily alter torque levels to meet supplemental goals (e.g., torque management for transmissions shifts). These features can lead to lower-than-peak torque levels with the current engine mapping procedure. We are assessing a potential requirement that the torque curve established during the mapping procedure must represent the highest torque level possible for the test fuel. This could be achieved by various approaches, including disabling temporary conditions or operational states in the electronic controls during the mapping, or using a different order of speed and load points (e.g., sweeping up, down, or sampling at a speed point over a longer time to allow stabilization) to generate peak values. We seek comment on the need to update our current engine mapping procedure for gasoline engines.

C. In-Use Emission Standards

Heavy-duty diesel engines are currently subject to Not-To-Exceed (NTE) standards that are not limited to specific test cycles, which means they can be evaluated during in-use operation.

[97] 40 CFR 1065.510.

In-use data are collected by manufacturers as described in Section III.F.3. The data is then analyzed pursuant to 40 CFR 86.1370 and 40 CFR 86.1912 to generate a set of engine-specific NTE events – that is, 30-second intervals for which engine speeds and loads remain in the control area. There is no specified test cycle for these standards; the express purpose of the NTE test procedure is to apply the standard to engine operation conditions that could reasonably be expected to be seen by that engine in normal vehicle operation and use, including a wide range of real ambient conditions.

EPA refers to the range of engine operation where the engine must comply with the NTE standards as the "NTE zone." The NTE zone excludes operating points below 30% of maximum torque or below 30% of maximum power. The NTE zone also excludes speeds below 15% of the European Stationary Cycle speed. Finally, the NTE procedure also excludes certain operation at high altitudes, high intake manifold humidity, or at aftertreatment temperatures below 250°C. Data collected in-use is considered a valid NTE event if it occurs within the NTE zone, lasts 30 seconds or longer, and does not occur during any of the exclusion conditions mentioned previously (engine, aftertreatment, or ambient).[98]

NTE standards have been successful in broadening the types of operation for which manufacturers design their emission controls to remain effective. However, our analysis of existing in-use test data indicates that less than five percent of a typical time-based dataset are valid NTE events that are subject to the in-use NTE standards; the remaining data are excluded. Furthermore, we found that emissions are high during many of the excluded periods of operation,

[98] For more on our NTE provisions, see 40 CFR 86.1362.

such as when the aftertreatment temperature drops below the catalyst light-off temperature. For example, 96 percent of tests from 2014, 2015, and 2016 in-use testing orders passed with NOx emissions for valid NTE events well below the 0.3 g/hp-h NTE standard. When we used the same data to calculate NOx emissions over *all* operation measured, not limited to valid NTE events, the NOx emissions were more than double (0.5 g/hp-h).[99] The results were higher when we analyzed the data to only consider NOx emissions that occur during low load events. These results suggest there may be great potential to improve in-use performance by considering more of the engine operation when we evaluate in-use compliance.

The European Union "Euro VI" emission standards for heavy-duty engines require in-use testing starting with model year 2014 engines.[100,101] Manufacturers must check for "in-service conformity" by operating their engines over a mix of urban, rural, and freeway driving on prescribed routes using portable emission measurement system (PEMS) equipment to measure emissions. Compliance is determined using a work-based windows approach where emissions data are evaluated over segments or "windows." A window consists of consecutive 1 Hz data points that are summed until the engine performs an amount of work equivalent to the European transient engine test cycle (World Harmonized Transient Cycle). EPA and others have compared the performance of US-certified engines and Euro VI-certified engines and concluded that the

[99] Hamady, Fakhri, Duncan, Alan. "A Comprehensive Study of Manufacturers In-Use Testing Data Collected from Heavy-Duty Diesel Engines Using Portable Emissions Measurement System (PEMS)". 29th CRC Real World Emissions Workshop, March 10 -13, 2019.

[100] COMMISSION REGULATION (EU) No 582/2011, May 25, 2011. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02011R0582-20180118&from=EN.

[101] COMMISSION REGULATION (EU) 2018/932, June 29, 2018. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0932&from=EN.

European engines' NOx emissions are comparable to US 2010 standards-certified engines under city and highway operation, but lower in light-load conditions.[102], This suggests that manufacturers respond to the Euro VI test procedures by designing their emission controls to perform well over broader operation. EPA intends the CTI to expand our in-use procedures to capture nearly all real-world operation. We are considering an approach similar to the European in-use program, with key distinctions that improve upon the Euro VI approach, as discussed below.

Most importantly, we are not currently intending to propose prescribed routes for our in-use compliance test program. Our current program requires data to be collected in real-world operation and we would consider it an unnecessary step backward to change that aspect of the procedure. In what we believe to be an improvement to a work-based window, we are considering a moving average window (MAW) approach consisting of time-based windows. Instead of basing window size on an amount of work, we are evaluating window sizes ranging from 180 to 300 seconds.[103] The time-based windows would be intended to equally weight each data point collected.

We also recognize that it would be difficult to develop a single standard that would be appropriate to cover the entire range of operation that heavy-duty engines experience. For example, a numerical standard that would be technologically feasible under worst case

[102] Rodriguez, F.; Posada, F. "Future Heavy-Duty Emission Standards An Opportunity for International Harmonization". The International Council on Clean Transportation. November 2019. Available online: https://theicct.org/sites/default/files/publications/Future%20_HDV_standards_opportunity_20191125.pdf

[103] Our evaluation includes weighing our current understanding that shorter windows are more sensitive to measurement error and longer windows make it difficult to distinguish between duty cycles.

conditions such as idle, would necessarily be much higher than the levels that are feasible when the aftertreatment is functioning optimally. Thus, we are considering separate standards for distinct modes of operation. Our current thinking is to group the second-by-second in-use data into one of three bins using a "normalized average CO_2 rate" from the certification test cycles to identify the boundaries.[104] Data points with a normalized average CO_2 rate greater than 25 percent (equivalent to the average power of the current FTP) could be classified as medium-/high-load operation and binned together. We are considering two options for identifying idle data points. The first option would use a vehicle speed less than 1 mph. The second option would use the normalized average CO_2 rate of a low-load certification cycle.[105] The remaining data points, bounded by the idle and medium-/high-load bins, would contribute to the low-load bin data.

We are considering several approaches for evaluating the emissions performance of the binned data. One approach would sum the total NOx mass emissions divided by the sum of CO_2 mass emissions. This "sum-over-sum" approach would successfully account for all NOx emissions; however, it would require the measurement system (PEMS or a NO_X sensor) to be accurate across the complete range of emissions concentrations. We are also considering the advantages and disadvantages other statistical approaches that evaluate a high percentile of the data instead of the full set. We request comment on all aspects of a moving average window

[104] We plan to propose that "normalized average CO_2 rate" be defined as the mass of NOx (in grams) divided by the mass of CO_2 (in grams) and converted to units of mass of NOx per unit of work by multiplying by the work-specific CO_2 emissions value. Our current thinking is to use the work-specific CO_2 value reported to EPA as part of the engine's family certification level (FCL) for the FTP certification cycle.

[105] The low load cycle proposed by CARB has an average power of eight percent.

analysis approach. Commenters are encouraged to share the benefits and limitations of the window sizes, binning criteria, and performance calculations introduced here, as well as other strategies EPA should consider. We also request data providing time and cost estimates for implementing a MAW-based in-use program and what aspects of this approach could be phased-in to reduce some of the upfront burden.

As mentioned previously, we are considering a separate MAW-based standard for each bin. In our current NTE-based program, the NTE standards are 1.5 times the certification duty-cycle standards. Similarly, for the MAW-based standards, we could design our certification and in-use programs to include corresponding laboratory-based cycles and in-use bins with emission standards that relate by a scaling factor. Alternatively, a percentile-based performance evaluation may make a scaling factor unnecessary. We request comment on appropriate scaling factors or other approaches to setting MAW-based standards. Finally, we request comment on whether there is a continued need for measurement allowances in an in-use program such as described above.

D. Extended Regulatory Useful Life

Under the Clean Air Act, an engine or vehicle's useful life is the period for which the manufacturer must demonstrate, to receive EPA certification, that the engine or vehicle will meet the applicable emission standard, including accounting for deterioration over time. Section 207(c) of the Act requires manufacturers to recall and repair engines if "a substantial number of any class or category" of them "do not conform to the regulations . . . when in actual use throughout their useful life." Thus, there are two critical implications for the length of the useful life: (1) it defines the emission durability the manufacturer must demonstrate for certification, and (2) it is the period for which the manufacturer is liable for compliance in-use. With respect to the durability demonstration, manufacturers can either show that the components will generally last the full useful life and retain their function in meeting the applicable standard, or show that they will be replaced at appropriate intervals by owners.

Section 202(d) of the Act directs EPA to "prescribe regulations under which the useful life of vehicles and engines shall be determined" and establishes minimum values of 10 years or 100,000 miles, whichever occurs first. The Act authorizes EPA to adopt longer periods that we determine to be appropriate. Under this authority, we have established the following useful life mileage values for heavy-duty engines:[106]

- 110,000 miles for gasoline-fueled and light heavy-duty diesel engines
- 185,000 miles for medium heavy-duty diesel engines
- 435,000 miles for heavy heavy-duty diesel engines

Analysis of in-use mileage accumulation and typical rebuild intervals shows that current regulatory useful life values are much lower than actual in-use lifetimes of heavy-duty engines and vehicles. In 2013, EPA commissioned an industry characterization report that focused on heavy-duty diesel engine rebuilds.[107] The report relied on existing data from MacKay & Company surveys of heavy-duty vehicle operators. An engine rebuild was categorized as either

[106] EPA adopted useful life values 110,000, 185,000, and 290,000 miles for light, medium, and heavy heavy-duty engines (respectively) in 1983. (48 FR 52170, November 16, 1983). The useful life for heavy heavy-duty engines was subsequently increased to 435,000 miles for 2004 and later model years. (62 FR 54694, October 21, 1997).

[107] ICF International, "Industry Characterization of Heavy Duty Diesel Engine Rebuilds" EPA Contract No. EP-C-12-011, September 2013.

an in-frame overhaul (where the rebuild occurred while the engine remained in the vehicle) or as an out-of-frame overhaul (where the engine was removed from the vehicle for somewhat more extensive service). We believe an out-of-frame overhaul is a reasonable estimate of a heavy-duty engine's primary operational life.[108] The following average mileage values were associated with out-of-frame overhauled engines from each of the heavy-duty vehicle classes in the report:

- Class 3: 256,000 miles
- Class 4: 346,300 miles
- Class 5: 344,200 miles
- Class 6: 407,700 miles
- Class 7: 509,100 miles
- Class 8: 909,900 miles

We translated these vehicle classes to EPA's regulatory classes for engines assuming Classes 3, 4, and 5 represent light heavy-duty diesel engines (LHDDEs), Classes 6 and 7 represent medium heavy-duty diesel engines (MHDDEs) and Class 8 represents heavy heavy-duty diesel engines (HHDDEs). The resulting average rebuild ages for LHDDE, MHDDE, and HHDDE are 315,500; 458,400; and 909,900, respectively.[109] The current regulatory useful life of today's engines covers less than half of the primary operational life of HHDDEs and MHDDEs and less than a third of LHDDEs – assuming the engines are only overhauled one time. We welcome

[108] In-frame rebuilds tend to be less complete and occur at somewhat lower mileages.

[109] Note that these mileage values reflect replacement of engine components, but do not include aftertreatment components. At the time of the report, the population of engines equipped with DPF and SCR technologies was limited to relatively new engines that were not candidates for rebuild.

comment on the average number of times an engine core receives an overhaul before being scrapped. We are also requesting comment on the whether the 2013 EPA report continues to reflect modern engine rebuilding practices.

We see no reason to change the useful life values with respect to years. However, based on available data, we intend to propose new useful life mileage values for all categories of heavy-duty engines to be more reflective of real-world usage. Although we are continuing to analyze the issue, we may propose to base the new useful life values for engines on the median or average period to the first rebuild, measured as mileage at the first out-of-frame overhaul. The reason to tie useful life to rebuild intervals stems from the changes to an engine when it is rebuilt. Rebuilding involves disassembling significant parts of the engine and replacing or remachining certain combustion-related components.

We are also evaluating the useful life for gasoline engines. Beginning no later than model year 2021, *chassis-certified* heavy-duty gasoline vehicles are subject to a 150,000-mile useful life. We request comment on whether this would be the appropriate value for heavy-duty gasoline *engines*, or if a higher value would be more appropriate. Consistent with Section III.A.2.i, we would expect to apply the same useful life for evaporative emissions technologies.

A direct result of longer useful life values would be to require manufacturers to change their durability demonstrations. Currently manufacturers measure emissions from a representative engine as they accumulate service hours on it. If we extend useful life with no other changes to this approach, manufacturers would need to extend this durability testing out further.[110] We request comment on alternative approaches that should be considered. For example, we could allow manufacturers to base the durability demonstration on component replacement if manufacturers could demonstrate that the component would actually be replaced in use. EPA has previously stated that a manufacturer's commitment to perform the component replacement maintenance free of charge may be considered adequate, depending on the component. See 40 CFR 86.004-25 and related sections for other examples of how a manufacturer could potentially demonstrate durability.

In conversations with rebuilding facilities, it appears that aftertreatment components typically remain with the vehicle when engines are rebuilt out of frame and are not part of the rebuild process. We request comment on the performance and longevity of the aftertreatment components when the engine has reached the point of requiring a rebuild. Currently, aftertreatment components are covered by the useful life of the engine overall. While our current logic, explained above, would not support proposing useful life values for the entire engine that extend beyond the rebuild interval, it may not be appropriate for the durability requirements for the aftertreatment to be limited by the rebuild interval for the rest of the engine if current aftertreatment systems remain in service much longer. Thus, we are requesting comment on how to treat such components, including whether there is a need for separate provisions for aftertreatment components. One potential approach could be to establish a longer useful life for

[110] See Section III.F.4, which describes potential opportunities to streamline our durability demonstration requirements.

such components. However, we are also considering the possibility of requiring an a more extensive durability demonstration for such parts. For example, this might include a more aggressive accelerated aging protocol or an engineering analysis demonstrating a greater resistance to catalyst deterioration.

Another approach could be to develop a methodology to incorporate aftertreatment failure rates reflective of real-world experiences into engine deterioration factors at the time of certification, using methodology similar to incorporation of infrequent regeneration adjustment factors ("IRAF"). In 2018, CARB published an Initial Statement of Reasons document regarding proposed amendments to heavy-duty maintenance and warranty requirements. This document includes analysis of warranty data indicating that emission components for heavy heavy-duty engines had failure rates ranging from 1-17 percent, while medium heavy-duty engines had emission component failure rates ranging from 0-37 percent.[111,112] ARB did this analysis using data from MY2012 engines, as this was the only model year with a complete five-year history. That model year included the phase-in of advanced emission controls systems, which may have an impact on failure rates compared to other model years. EPA is seeking comment on whether these rates reflect component failures for other model year engines and information on representative failure rates for all model years.

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[111] California Air Resources Board, "Public Hearing to Consider Proposed Amendments to California Emission Control System Warranty Regulations and Maintenance Provisions for 2022 and Subsequent Model Year On-road Heavy-Duty Diesel Vehicles and Heavy-Duty Engines with Gross Vehicle Weight Ratings Greater Than 14,000 pounds and Heavy-Duty Diesel Engines in such Vehicles. Staff Report: Initial Statement of Reasons" May 2018. Available at: https://ww3.arb.ca.gov/regact/2018/hdwarranty18/isor.pdf.

[112] California Air Resources Board, Appendix C: Economic Impact Analysis/Assessment to the Heavy-Duty Warranty Initial Statement of Reasons, page C-8. June 28, 2018. Available online: https://ww3.arb.ca.gov/regact/2018/hdwarranty18/appc.pdf

E. Ensuring Long-Term In-Use Emissions Performance

As discussed above, deterioration of emission controls can increase emissions from in-use vehicles. Such deterioration can be inherent to the design and materials of the controls, the result of component failures, or the result of mal-maintenance or tampering. We are requesting comment on ways to reduce in-use deterioration of emissions controls from all sources. We have identified five key areas of potential focus and seek comment on the following topics:

- Warranties that cover an appropriate fraction of engine operational life
- Improved, more tamper-resistant electronic controls
- Serviceability improvements for vehicles and engines
- Education and potential incentives
- Engine rebuilding practices that ensure emission controls are functional

We believe addressing these five areas could offer a comprehensive strategy for ensuring in-use emissions performance over more of an engine's operational life.[113] The following sections describe possible provisions we believe could especially benefit second or third owners of future engines who, under the current structure, may not have access to resources for maintaining compliance of their higher-mileage engines.

1. <u>Lengthened Emissions Warranty</u>

Section 207(a) of the Clean Air Act requires manufacturers to provide an emissions warranty. This warranty offers protection for purchasers from costly repairs of emission controls during the

[113] Memorandum to Docket EPA-HQ-OAR-2019-0055. "Enhanced and Alternative Strategies to Achieve Long-term Compliance for Heavy-Duty Vehicles and Engines; the WISER Strategy", Amy Kopin, December 12, 2019.

warranty period and generally covers all expenses related to diagnosing and repairing or replacing emission-related components.[114] EPA has established by regulation the warranty periods for heavy-duty engines to be whichever comes first of 5 years or 50,000 to 100,000 miles, depending on engine size (see 40 CFR 86.085). However, due to the high annual mileage accumulation of many trucks, our early assessment is that the current warranty periods are insufficient for real-world operations. For example, today's mileage requirements may represent less than a single year's worth of coverage for some Class 8 vehicles.[115] We welcome comment on annual vehicle miles travelled for different classes and vocations.

We intend to propose longer emissions warranty periods. A longer emissions warranty period could provide an extended period of protection for purchasers, as well as a greater incentive for manufacturers to design emission control components that are more durable and less costly to repair. Longer periods of protection for purchasers could provide a greater incentive for owners to appropriately maintain their engines and aftertreatment systems so as not to void their warranty. Designing more durable components could help reduce the potential for problems later in the vehicle life that lead to breakdowns and recalls. For instance, in at least one recent recall related to certain SCR catalysts in heavy-duty vehicles, the recall was not announced until nearly nine years after the initial sale of these engines; as such, there was a prolonged period of real-world emissions increases, and some owners likely absorbed significant cost and downtime

[114] See 40 CFR 1068.115 and Appendix I to Part 1068 for a list of covered emission-related components.

[115] American Transportation Research Institute, "An Analysis of the Operational Costs of Trucking: 2017 Update" October 2017. Available here: https://truckingresearch.org/wp-content/uploads/2017/10/ATRI-Operational-Costs-of-Trucking-2017-10-2017.pdf.

for repairs that could have been covered by an extended warranty.[116,117] More durable parts could also lead to fewer breakdowns, which would likely reduce the desire for owners to tamper with emissions controls by bypassing DPF or SCR systems. In addition, extended warranties would result in additional tracking by OEMs of potential defect issues, which would increase the likelihood that emission defects (such as those involved in the recent recall) would be corrected in a timely manner. We request comment on emission component durability, as well as maintenance or operational strategies that could substantially extend the life of emission components and any regulatory barriers to implementing these strategies.

By rule, manufacturers providing a basic mechanical warranty must also cover emission related repairs for those same components.[118] Most engine manufacturers offer a 250,000-mile base warranty on their heavy heavy-duty engines, which already exceeds the current minimum 100,000-mile emission warranty requirement. We request comment on an appropriate length of emissions warranty period for engine and aftertreatment components to incentivize improved durability with reasonable cost.

One mechanism to maintain lower costs for a longer emissions warranty period could be to vary the length of warranty coverage across different types of components. For example, certain components (e.g., aftertreatment components) could have a longer warranty period. Commenters

[116] U.S. Environmental Protection Agency. "EPA Announces Largest Voluntary Recall of Medium- and Heavy-Duty Trucks." July 31, 2018. Available online: https://www.epa.gov/newsreleases/epa-announces-largest-voluntary-recall-medium-and-heavy-duty-trucks.

[117] Jaillet, James, "Volvo setting aside $780M to address emission system degradation problem" January 4, 2019. Available here: https://www.ccjdigital.com/volvo-setting-aside-780m-to-address-emissions-system-degradation-problem/ Accessed 10/2/19.

[118] See 40 CFR 86.004-2, definition of "warranty period".

are encouraged to address whether warranty should be tied to longer useful life, as well as whether the warranty period should vary by component and/or engine category.

With traditional warranty structures, parts and labor are covered 100 percent throughout a limited warranty period. We welcome comments addressing whether there would be value in alternative approaches. Figure 2 below provides a high-level illustration of alternative approaches to the traditional warranty structure. For example, there could be longer, prorated warranties that provide different levels of warranty coverage based on a vehicle's age or mileage. In addition, the warranty could be limited to include only certain parts after a certain amount of time, and/or not include labor for part, or even all, of the duration of coverage. We are seeking comment on any combination of these or other approaches. Commenters should consider discussing the components that could be included under each approach, and an appropriate period of time for given classes of vehicle and individual components. Commenters are encouraged to consider this issue in the context of the benefits of longer emissions warranty periods – namely providing an extended period of protection for purchasers, as well as a greater incentive for manufacturers to design emission control components that are more durable and less costly to repair.

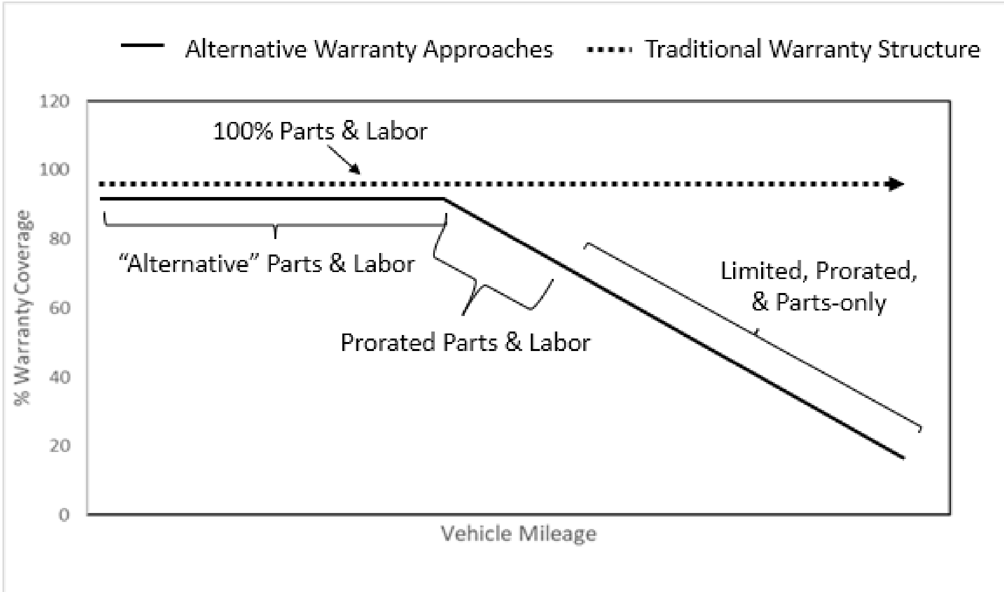

Figure 2 Alternative Warranty Approaches

2. Tamper-Resistant Electronic Controls

Although EPA lacks robust data on the frequency of tampering with heavy-duty engines and vehicles, enforcement activities continue to find evidence of tampering nationwide. Recently, EPA announced a new National Compliance Initiative ("NCI") that will include enhanced collaboration with states to reduce the manufacture, sale, and installation of defeat devices on vehicles and engines, with a focus on commercial truck fleets.[119]

We have identified several different ways that tampering can occur.[120] Most commonly, the engine's emission system parts are physically removed or "deleted" electronically through the

[119] Belser, Evan, "Tampering and Aftermarket Defeat Devices" Presented to the National Association of Clean Air Agencies. September 18, 2019. Available here: http://www.4cleanair.org/sites/default/files/resources/EPA%20Presentation%20to%20NACAA%20re%20Tampering%20and%20Aftermarket%20Defeat%20Device%20Sept%202019.pdf.

[120] U.S. Environmental Protection Agency, "Enforcement Data and Results", Available online: https://www.epa.gov/enforcement/enforcement-data-and-results. Accessed September 18, 2019.

use of software which can disable these components. One of the key methods to enable such actions is through tampering with the engine control module (ECM) calibration.

We are considering several approaches to prevent tampering with the ECM. One approach could be for manufacturers to provide public access to unique data channels that can be used by owners or enforcement agencies to confirm emission controls are active and functioning properly. A second approach to improved ECM security could be to develop methodologies that flag when ECMs are flashed with improper calibrations. This approach would require a process to distinguish between authorized and unauthorized flashing events, detect an unauthorized event, and store information documenting such events in the ECM. Finally, we are following ongoing work at SAE International that focuses on preventing cyber security hacking activity. The efforts to combat such safety- and security-related concerns may provide a pathway to apply similar solutions for emission control software and modules. We anticipate such a long-term approach would require effort beyond the CTI rulemaking timeframe. EPA requests comment on these or other actions we could take to help prevent ECM tampering.

3. Serviceability Improvements

Vehicle owners play an important role in achieving the intended emission reductions of the technologies that manufacturers implement to meet EPA standards. Vehicle owners are expected to properly maintain the engines, which includes scheduled (preventive) maintenance (e.g., maintaining adequate DEF supply for their diesel engines' aftertreatment) and repairs when components or systems degrade or fail. Although defective designs and tampering can contribute significantly to increased in-use emissions, mal-maintenance (which includes improper repairs, delayed repairs, and delayed or unperformed maintenance) also increases in-use emissions. Mal-maintenance (by owners or repair facilities) can result from:

- High costs to diagnose and repair
- Inadequate maintenance instructions
- Limited access to service information and specialized tools to make repairs

As discussed below, we are looking to improve in-use maintenance practices by addressing these factors. We also discuss how maintenance concerns can increase tampering.

We are especially interested in the repair and maintenance practices of second owners, which are typically individual owners and small fleets that do not have the sophisticated repair facilities of the larger fleets. These second owners often experience emission-related problems that cannot be diagnosed easily, causing the repairs to be delayed. While fleets often have sufficient resources to obtain engine manufacturer-specific diagnostic tools for their trucks and can diagnose emission-systems problems quickly, smaller fleets or individual owners may be required to tow their truck to a dealer to diagnose and address the problem.

In 2009, EPA finalized regulations for the heavy-duty industry to ensure that manufacturers make "service information" available to any person repairing or servicing heavy-duty vehicles and engines (see 74 FR 8309, February 24, 2009). This service information includes: information necessary to make use of the OBD system, instructions for making emission-related diagnoses and repairs, training information, technical service bulletins, etc. EPA is considering whether the service information and tools needed to diagnose problems with heavy-duty emission control systems are available and affordable. EPA requests comment on the following serviceability topics:

- Usefulness of currently available emission diagnostic information and equipment
- The adequacy of emission-related training for diagnosis and repair of these systems
- The readiness and capabilities of repair facilities in making repairs
- The reasonableness of the cost of purchasing this information and the equipment
- The prevalence of using of this equipment outside of large repair facilities
- If there are any existing barriers to enabling owners to quickly diagnose emission control system problems

We are currently evaluating which OBD signals are needed to diagnose and repair emission control components. While SAE's J1939 protocol establishes a comprehensive list of signals and parameters used in heavy-duty trucks, many signals are not required to be broadcast publicly. Ensuring that all owners, including those who operate older, higher-mileage vehicles, have access to service information to properly diagnose problems with their truck's emission system could reduce the cost for many owners who choose to do some maintenance on their own. Although J1939 includes nearly 2,000 parameters OBD regulations dictate a limited number of signals must be broadcast publicly. While today, some manufacturers broadcast more signals than are required, there is no guarantee that this practice will continue which could lead to loss of diagnostic ability. Therefore, we request comment on which signals we should require to be made available publicly to ensure adequate access to critical emissions diagnostic information.

Maintenance issues can result in owner dissatisfaction, which can incentivize removal or bypass of emission controls. EPA is aware of significant discontent expressed by owners concerning their experiences with emission systems on vehicles compliant with fully phased-in 2010 standards – in particular, for the first several model years after the new standards went into effect. Although significant improvements have been made to these systems since they were introduced into the market, reliability issues continue to cause concern for owners. For example, software and/or component failures can occur with little-to-no warning. Misdiagnosis can also lead to repeated repairs that don't solve the problem with the risk of repeated breakdowns, tows, and trips to repair facilities. We believe that reducing maintenance issues could also reduce tampering.

We are also evaluating the use of maintenance-inducing control features ("inducements") that degrade engine performance as a means to ensure that certain critical maintenance steps are performed. For example, SCR-equipped engines generally include features that "derate" or severely limit engine operation if a vehicle is operated without DEF. EPA guidance for such features was issued in 2009.[121] While inducements were designed to encourage owners to perform proper maintenance, an inducement can be triggered for a variety of reasons that an owner cannot control (e.g., faulty wiring, software glitches, or sensor failures) and may not degrade emission control performance. EPA understands that some owners view derate inducements as particularly problematic when they are not due to improper maintenance,

[121] U.S. Environmental Protection Agency. "Certification Requirements for Heavy-Duty Diesel Engines Using Selective Catalyst Reduction (SCR) technologies", February 18, 2009, CISD-09-04 (HDDE).

because they are difficult to predict and may occur at inconvenient locations, far from preferred repair facilities. Owners' prior concerns over parts durability and potential breakdowns are likely heightened by the risk of inducements. Given that we are nearing a decade of industry experience in understanding maintenance of SCR systems, we believe it is time to reevaluate these features, and potentially allow for less severe inducements. We believe such relief may also reduce tampering.

We broadly request comment on actions EPA should take, if any, to improve maintenance practices and the repair experience for owners. We welcome comment on the adequacy of existing emission control system maintenance instructions provided by OEMs. In addition, we request comment on whether other stakeholders (such as state and local agencies) may find it difficult in the field to detect tampering due to limitations of available scan tools and limited publicly available broadcast OBD parameters. We request comment on signals that are not currently broadcast publicly that would enable agencies to ensure vehicles are compliant during inspections.

4. <u>Emission Controls Education and Incentives</u>

In addition to more easily accessible service information for users, we believe that there may also be educational programs and voluntary incentives that could lead to better maintenance and real-world emission benefits. We understand that there continues to be misinformation in the marketplace regarding exhaust aftertreatment systems, including predatory websites that incorrectly indicate that their fuel economy-boosting delete kits are legal. We seek comment on the potential benefits of educational and/or voluntary, incentive-based programs such as EPA's

SmartWay program.[122] Such a program could provide online training on issues such as the importance of the emissions equipment, how it functions, how emissions systems impact fuel economy, users' ability to access service information, and how to identify legitimate methods and services that do not compromise their vehicles' emissions compliance. In addition to educational elements, we are seeking comment on whether and how to develop tools allowing fleets to commit to selling used vehicles with fully functional and verified emissions control systems.

5. Improving Engine Rebuilding Practices [123]

Under 40 CFR 1068.120(b), EPA defines requirements for rebuilding engines to avoid violating the tampering prohibition in 1068.101(b)(1). EPA supports engine rebuilding that maintains emissions compliance, but it is unclear if the rebuilding industry's current practices adequately address the functioning of aftertreatment systems during this process. We are interested in improving engine rebuilding practices to help ensure emission controls continue to function properly after an engine is rebuilt. In particular, we are concerned about components that typically remain with the vehicle when the engine is removed for rebuilding, especially aftertreatment components. Because these components may not be included when an engine is overhauled, we believe that additional provisions may be needed to help ensure that these other components maintain proper function to the same degree that the rebuilt components do.

[122] Learn about SmartWay. Available online at: https://www.epa.gov/smartway/learn-about-smartway. Accessed October 3, 2019.

[123] As used here, the term "rebuilding" generally includes practices known commercially as "remanufacturing". Under 40 CFR part 1068, rebuilding refers to practices that fall short of producing a "new" engine.

There are practical limitations to implementing new regulations that would include testing and repairing the aftertreatment system during each rebuild event. Currently, engine rebuilding is focused on the engine; aftertreatment systems may not be evaluated at the time of rebuild – especially when it remains with the vehicle during an out-of-frame rebuild. We recognize the potentially significant financial undertaking that might be necessary for the rebuilding industry to restructure their businesses to include aftertreatment systems in their processes.

Instead, our goal of proposing new regulations for rebuilding would be to ensure the aftertreatment system is functioning properly at the time of rebuild. We are considering a program where rebuilders would collect information documenting certain OBD codes to determine whether their emission systems are on the truck and functioning prior to placing an order for a factory-rebuilt engine or sending their engine out for rebuilding. This could consist of the engine rebuilder requesting that the owner provide them with a report showing the results of a limited number of OBD parameters that indicate broadly the status of the emissions systems. Such a program could involve the rebuilder ensuring this report has been received, reviewed, and retained. This sort of check would not be intended to impede the sale of the rebuilt engine. We acknowledge that some engines may have experienced catastrophic failures that may result in numerous "check engine" codes and prevent owners or repair facilities from running additional OBD monitors to confirm the aftertreatment system status.

We solicit comment on whether we could appropriately ensure compliance without creating unnecessary market disruption by requiring owners to attest that any problems shown in their engine's report will be repaired within a certain timeframe. We believe this documentation requirement would introduce a level of accountability with respect to aftertreatment systems when engines are rebuilt, with minimal burden on the rebuilders and owners. We request comment on the feasibility and challenges of such an approach, including suggestions of relevant OBD parameters, report format, and how to collect the information (e.g., could manufacturers build into new vehicles the ability for such a status report to be run using a generic scan tool and be output in a text file).

F. Certification and Compliance Streamlining

The fundamental requirements for certification of heavy-duty engines are specified by the Clean Air Act. For example, the Act provides:

- Manufacturers must obtain a certificate of conformity from EPA before introducing an engine into commerce
- Manufacturers must obtain new certificates each year
- The certificate must be based on test data
- The manufacturer must provide an emissions warranty to the purchaser

However, EPA has significant discretion for many aspects of our certification and compliance programs, and we are requesting comment on potential opportunities to streamline our requirements, while ensuring no change in protection for public health and the environment, including EPA's ability to ensure compliance with the requirements of the CAA and our regulations. Commenters are encouraged to consider not just potential cost savings associated with each aspect of streamlining, but also ways to prevent any adverse impacts on the effectiveness of our certification and in-use compliance program.

1. Certification of Carry-over Engines

Our regulations currently require engine families to undergo a thorough certification process each year. This includes "carry-over" engines with no year-to-year calibration or hardware changes. Although we have already adopted certain simplifications, we intend to consider additional improvements to this this process under the CTI to reduce the burden of certification for carry-over engines. We request comment on specific revisions that could apply for certifying carry-over engines.

2. Modernizing of Heavy-Duty Engine Regulations

Heavy-duty engine criteria pollutant standards and related regulations were codified into 40 CFR part 86 in the 1980s. We believe the CTI provides an opportunity to clarify (and otherwise improve) the wording of our existing heavy-duty criteria pollutant regulations in plain language and migrate them to part 1036. This part, which was created for the Phase 1 GHG program, provides a consistent, modern format for our regulations, with improved organization. This migration would not be intended to make any change to the compliance program, except as specifically and expressly addressed in the CTI rulemaking. We request comment on the benefits and concerns with this undertaking.

3. Heavy-Duty In-Use Testing Program

Under the current manufacturer-run heavy-duty in-use testing program, EPA annually selects engine families to evaluate whether engines are meeting current emissions standards. Once we submit a test order to the manufacturer to initiate testing, it must contact customers to recruit vehicles that use an engine from the selected engine family. The manufacturer generally selects five unique vehicles that have a good maintenance history, no malfunction indicators on, and are within the engine's regulatory useful life for the requested engine family. The tests require use of portable emissions measurement systems (PEMS) that meet the requirements of 40 CFR 1065 subpart J. Manufacturers collect data from the selected vehicles over the course of a day while they are used for their normal work and operated by a regular driver, and then submit the data to EPA.

EPA's current process for selecting an engine family test order is undefined and can be based on a range of factors including, but not limited to, recent compliance performance or simply length of time since last data collection on that family. Onboard NOx sensors present an opportunity to better define EPA's criteria for test orders. For example, onboard NOx data could be used to screen in-use engines for key performance characteristics that may indicate a problem. We welcome comment on possible strategies and challenges to incorporating onboard NOx sensor data in EPA's engine family test order process.

An evolution of our current PEMS-based in-use testing approach could be to use onboard NOx sensors that are already on vehicles instead of (or potentially in addition to) PEMS as the emission measurement tool for in-use compliance. In this scenario, manufacturers would collect and store performance data on the engine's computer until it is retrieved. When a test order is sent, manufacturers could simply collect the stored data and send it to EPA, reducing the burden of today's PEMS-based collection procedures. This simplified data collection could potentially expand the pool of vehicles evaluated for a given test order and compliance could be based on a much greater percentage of the in-use fleet with broader coverage of the industry's diverse operation. We are currently in the early stages of evaluating key questions for this type of evolution in approach to in-use testing. These key issues include: NOx sensor performance (noted in III.A.3), appropriate engine parameters to target, quantity of data to collect, performance metrics to calculate, and frequency of reporting. Additionally, we are evaluating several candidate processes for aggregating the results. See Section III.C for a discussion of our early thinking on these topics as they relate to potential updates to EPA's manufacturer-run in-use testing program.

Another aspect of this potential evolution in the in-use testing program could be combining the use of onboard sensors with telematic communication technologies that facilitate manufacturers receiving and sending information from/to the vehicle in real time. Telematics services are already increasingly used by the industry due to the Department of Transportation's Federal Motor Carrier Safety Administration's Electronic Logging Device (ELD) Rule that requires the use of ELDs by the end of 2019.[124] The value of being able to measure NOx emissions from the in-use fleet could be increased if coupled with real-time communication between the engine manufacturers and the vehicles. For example, such a combination could enable manufacturers to identify emission problems early. By being able to schedule repairs proactively or otherwise respond promptly, operators would be able to prevent or mitigate failures during in-use operation and make arrangements to avoid disrupting operations. We

[124] DOT Federal Motor Carrier Safety Administration. "ELD Factsheet," Available online: https://www.fmcsa.dot.gov/hours-service/elds/eld-fact-sheet-english-version.

request comment on the potential use of telematics and communication technology in ensuring in-use emissions compliance.

Finally, we request comment on the need to measure PM emissions during in-use testing of DPF-equipped engines – whether under the current regulations or under some future program. PEMS measurement is more complicated and time-consuming for PM measurements than for gaseous pollutants such as NOx and eliminating it for some or all in-use testing would provide significant cost savings. Commenters are encouraged to address whether there are less expensive alternatives for ensuring that engines meet the PM standards in use.

4. Durability Testing

Pursuant to Clean Air Act Section 206, EPA's regulations require that a manufacturer's application for certification include a demonstration that the new engines will meet applicable emission standards throughout the engines' useful life. This is often called the durability demonstration. The core of this demonstration includes procedures to calculate a deterioration factor (DF) to project full useful life emissions compliance based on testing a low-hour engine.[125]

A deterioration factor can be determined directly for heavy-duty diesel engines by aging the engine and exhaust aftertreatment system to full useful life on an engine dynamometer. This time-consuming process requires manufacturers to commit to product configurations well ahead of their pre-production certification testing in order to ensure the durability testing is complete.

[125] 40 CFR 86.1823-08

Some manufacturers run multiple, staggered durability tests in parallel in case a component failure occurs that would require a complete restart of the aging process.

Recognizing that full useful life testing is a significant undertaking (that can involve more than one full year of continuous engine operation for heavy heavy-duty engines), EPA has allowed manufacturers to age their systems to between 35 and 50 percent of full useful life on an engine dynamometer and extrapolate the data to full useful life. This extrapolation reduces the time to complete the aging process, but it is unclear if it accurately captures the emissions deterioration of the system.

i. Diesel Aftertreatment Rapid Aging Protocol

The current durability demonstration provisions were developed before aftertreatment systems were widely adopted for emission control and we believe some of the inaccuracy of the deterioration extrapolation may be due to the deterioration mechanisms unique to catalysts. We believe a more cost-efficient demonstration protocol could focus on the emissions-critical catalytic aftertreatment system to accelerate the process and possibly improve accuracy.

EPA is developing a protocol for demonstrating aftertreatment durability through an accelerated catalyst aging procedure. The objective of this protocol is to artificially recreate the three primary catalytic deterioration processes observed in field-aged components: thermal aging based on time at high temperature, chemical aging that accounts for poisoning due to fuel and oil contamination, and deposits. This work to develop a diesel aftertreatment rapid-aging protocol (DARAP) builds on an existing rapid-aging protocol designed for light-duty gasoline vehicles (64 FR 23906).

A necessary feature of this protocol development would be a process to validate deterioration projections from accelerated aging. Three engines and their corresponding aftertreatment systems will be aged using our current, engine-focused durability test procedure. Three comparable aftertreatment systems will be aged using a burner in place of an engine. We are planning to evaluate emissions using this accelerated approach, compared to the standard approach, at the following approximate intervals: 0; 280,000; 425,000; 640,000; and 850,000 miles.

We anticipate this validation program will take six months per engine platform. We expect the program will be completed after the CTI NPRM is issued. We plan to have results from one of the test engines in time to consider when developing the proposal, with the remaining results and final report completed before the final rulemaking. We request comment on the need, usefulness and appropriateness for a diesel aftertreatment rapid-aging protocol, and we request comment on the test program EPA has initiated to inform the accelerated durability demonstration method outlined here.

ii. Durability Certification

As mentioned previously, EPA has issued guidance to ensure manufacturers report accurate deterioration factors. EPA is considering updates to the durability demonstration currently required for manufacturers, which may still require manufacturers to validate their reported values. We believe onboard data collected for in-use compliance could provide a pathway for manufacturers to show the deterioration performance of their engines in the real world with reduced need for upfront durability demonstrations. We request comment on the suitability of onboard data to supplement our current or future deterioration factor demonstrations, as well as opportunities to reduce testing burden by reporting in-use data.

G. Incentives for Early Emission Reductions

The Clean Air Act requires that EPA provide manufacturers sufficient lead time to meet new standards. However, we recognize that manufacturers may have opportunities to introduce some technologies earlier than required, and that public health and the environment could benefit from such early introduction. Thus, we are requesting comments on potential provisions that would provide a regulatory incentive for reducing emissions earlier than required, including but not limited to incentives for low-emission, advanced powertrain technologies.[126] Such approaches can have the effect of accelerating the turnover of the existing fleet of heavy-duty vehicles to lower-emitting vehicles.

We have often relied on emission credit banking provisions, such as those in 40 CFR 1036.715, to incentivize early emission reductions. This approach has worked well for rulemakings that set numerically lower standards but keep the same test cycles and other procedures. However, this would not necessarily be the case for the CTI, where we expect to adopt new test cycles or other fundamentally new approaches. Manufacturers could generate and bank emission credits for the two current EPA test cycles (the FTP and RMC) in the near-term, but it is unclear how those credits could be used to show compliance with respect to operating modes that are not reflected in the current cycles.

[126] See Section III.A.4 for more discussion on advanced powertrain technologies.

Manufacturers could certify to any new CTI provisions once the rule is finalized, but that may not leave sufficient time for manufacturers to complete all of the steps required to certify new engines early. For example, manufacturers would not know the new useful life mileages until the rule is finalized, which may hinder them from completing durability work early. Therefore, we request comment on alternative approaches to incentivize early emission reductions.

In particular, we would be interested in the early adoption of technology that reduces low-load emissions. One approach we are considering would be for manufacturers to certify engines with new technology to the existing requirements (i.e., FTP and RMC test cycles and durability demonstration), but then track the engines in-use using improved in-use provisions. This approach could demonstrate that the engines have lower emissions in use than other engines (including low-load operation) and serve as a pilot program for an updated in-use program. We request comment on options to potentially generate numerical off-cycle credit under this approach, or other interim benefits, such as delayed compliance for some other engine family, that could incentivize early emissions reductions.

IV. Next Steps

As described above, EPA has made important progress in the development of technical information to support new, more stringent NOx emission standards and other potential program elements. We also expect to receive additional technical information in the comments on this ANPR. We intend to publish a NPRM next year, after reviewing the comments and considering how any new information we receive may be used in the analysis we have underway to support the CTI NPRM.

See the PUBLIC PARTICIPATION section at the beginning of this notice for details on how to submit comments.

V. Statutory and Executive Order Reviews

Under Executive Order 12866, entitled Regulatory Planning and Review (58 FR 51735, October 4, 1993), this is not a "significant regulatory action." Because this action does not propose or impose any requirements, the various statutes and Executive Orders that apply to rulemaking do not apply in this case. Should EPA subsequently pursue a rulemaking, EPA will address the statutes and Executive Orders as applicable to that rulemaking. Nevertheless, the Agency welcomes comments and/or information that would help the Agency to assess any of the following:

- The potential impact of a rule on small entities pursuant to the Regulatory Flexibility Act (RFA) (5 U.S.C. 601 et seq.);
- Potential impacts on federal, state, or local governments pursuant to the Unfunded Mandates Reform Act ((UMRA) (2 U.S.C. 1531-1538);
- Federalism implications pursuant to Executive Order 13132, entitled Federalism (64 FR 43255, November 2, 1999);
- Availability of voluntary consensus standards pursuant to section 12(d) of the National Technology Transfer and Advancement Act of 1995 (NTTAA), Public Law 104-113;
- Tribal implications pursuant to Executive Order 13175, entitled Consultation and Coordination with Indian Tribal Governments (65 FR 67249, November 6, 2000);

- Environmental health or safety effects on children pursuant to Executive Order 13045, entitled Protection of Children from Environmental Health Risks and Safety Risks (62 FR 19885, April 23, 1997) - applies to regulatory actions that: (1) concern environmental health or safety risks that EPA has reason to believe may disproportionately affect children and (2) are economically significant regulatory action, as defined by Executive Order 12866;
- Energy effects pursuant to Executive Order 13211, entitled Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use (66 FR 28355, May 22,2001);
- Paperwork burdens pursuant to the Paperwork Reduction Act (PRA) (44 U.S.C. § 3501); or
- Human health or environmental effects on minority or low-income populations pursuant to Executive Order 12898, entitled Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (59 FR 7629, February 16, 1994).

The Agency will consider such comments during the development of any subsequent proposed rulemaking.

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Dated:

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Andrew R. Wheeler,

Administrator.