Peer Review Comments and EPA Responses: Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES201X

December 2020

Peer review is an important element in ensuring the quality and integrity of the MOVES model. Peer review for the exhaust emission rates for heavy-duty vehicles inputs for MOVES was carried out under procedures described in the EPA Peer Review Handbook.[1] A contractor managed the peer review process, selecting qualified independent experts and arranging for letter reviews.

This document lists the comments received from peer reviewers on selected sections from two September 2017 draft MOVES reports:

1. Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES201X
    - Updated MY 2010+ diesel emission rates (running, start, extended idle)
        - *Section 2.1. – Running Exhaust Emissions*
        - *Section 2.1.2.2.8 Computation of Elemental Carbon and Non-Elemental Carbon Emission Factors*
        - *Section 2.1.4. Energy*
        - *Section 2.2.- Start Exhaust Emissions*
        - *Section 2.3. – Extended Idling Exhaust Emissions*
    - Updated heavy-duty gasoline emission rates
        - *Section 3.1.3 Energy Consumption for Heavy-duty Gasoline Vehicles Updated heavy-duty CNG emission rates*
        - *Section 3.2.3 Soak Time Adjustments*
    - *Updated heavy-duty CNG emission rates*
        - *Section 4 Introduction and Section 4.2. – Development of Running Exhaust Emission Rates*
        -
2. Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X
    - *Section 3: Humidity Adjustments*

The specific sections and charge questions, including supplemental material for the questions, are included in the charge questions located with the peer-review material. Reviewer comments on minor formatting issues and typos are omitted. The peer-reviewed report, charge questions to the peer-reviewers and received peer-review comments, and other associated peer-review materials are located on EPA's science inventory webpage.[2]

In this document, report section headings and EPA questions to the reviewers are listed in bold; reviewer comments are in normal text; EPA response to the comments is in italic.

In response to the peer-review comments, we have made updates to Exhaust Emission Rates for Heavy-duty Onroad Vehicles in MOVES3.[3] As discussed in the EPA responses, we did not update the humidity adjustments in response to the review of the Emission Adjustments for

Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES3.[4] The proposed humidity updates were not incorporated into MOVES3 because they required code changes which have not yet been incorporated into MOVES3. We anticipate they will be included in a future release of MOVES. The humidity adjustments are unchanged from MOVES2014b.

Many of the updates documented in this report were also made to a draft version of MOVES3 that is intended to be used to support the emissions analysis of the Cleaner Trucks Initiative (CTI). The updates made to the draft MOVES3 version used for the CTI analysis from MOVES2014b will be documented in separate MOVES reports. We have attempted to clarify updates that addressed differently for draft MOVES version used for the CTI and MOVES3 (See the EPA response to the first specific question from both reviewers)

Note the section, table, and figure references made by the peer-reviewers refer to the September 2017 version of the report and may no longer be consistent with the MOVES3 heavy-duty exhaust report. The EPA responses reference sections, tables and figures in the published MOVES3 report.

Comments from Arvind Thiruvengadam Ph.D.

Dr. Thiruvengadam peer-reviewed sections the of the report in September 2017 according to the charge outlined in the previous section. At the time of this review, Dr. Thiruvengadam was an Assistant Professor with the Department of Mechanical and Aerospace Engineering and the Center for Alternative Fuels, Engines, and Emissions at West Virginia University. Dr. Thiruvengadam's comments are unedited but formatted to be consistent with the format of this report. EPA responses to the comments are in italic.

Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES201X

General Questions
The report was very informative and I have suggested comments based on my experience and understanding of the methodologies documented in the report. Overall the approach, methodologies and data sources used for the development and upgrade of the MOVES model are very sound. The report identifies holes in the data, which published literature does not discuss and some of the information would require dedicated research to fill the gap.

No Response Needed

Section 2.1 Heavy-Duty Vehicle Emissions

2.1.1.1: Data Sources: The EPA has used data from 3 main sources; a) ROVER, b) Consent Decree Testing, c) HDIUT testing, d) Houston drayage data. The three data sources represent heavy-duty vehicle emissions for three distinct time periods of stringency in emission standards. The quality of the data is representative of the analyzer technology available during the different time periods. Reviewer believes it is important to mention the accuracy levels of the analyzers that were used during the collection of data. If exact values are not available, reviewer believes it is important to caveat that "data collected during ROVER and Consent decree testing could have higher variation due to the use of prototype PEMS equipment". The current technology PEMS equipment are comparable to laboratory grade analyzers and maybe associated with lesser variations and errors. Are the emissions rates from in-use testing corrected for measurement errors? In other words, was a measurement allowance added to the reported values?

Response: The following text was added to a new subsection (Section 2.1.1.2) in the main report after a brief description of the data sets:

"PEMS devices continue to make improvements that affect measurement accuracy, such as sensor response, sample conditioning, and noise reduction. The data sets represent the accuracy of the instruments at the time of measurement. In compliance determinations, when determining whether the tested vehicle meets the in-use emissions standard or not, an "accuracy margin for portable in-use equipment" (commonly referred to as measurement allowance) is added onto the standard; increasing the vehicle compliance margin. The accuracy margins vary by model year and type of measurement method and are described in 40 CFR 86.1912. This is done to prevent measurements that are biased-high from affecting the compliance decision. However, since the true value for each second of data is unknown and errors could be biased either high or low, the in-use emission rates used in MOVES

from each of these data sets are not adjusted to reflect the measurement allowance."

The report clearly explains the additional data processing (time alignment, completeness of data, etc.) and data filtering performed by EPA before incorporation into the model. This section of the report does not seem to indicate the check for carbon balance versus ECU reported fueling as another sanity check to validate exhaust flow measurement and or CO2 measurement. Was this analysis performed by EPA or did the EPA rely only on the data providers to perform this analysis? I believe the exhaust flow measurement system is subject to a lot of errors associated with condensation and drift of pressure transducers, hence this analysis is important to check for accuracy of measuring mass flow of exhaust.

Response: The HDIU data used to update the 2010 MY+ emission rates were gathered by the manufacturers and submitted to EPA as required by EPA regulations. We added this text to the new subsection Section 2.1.1.2 where we describe the checks on the HDIUT data used for MY 2010+ emissions rate update:

"We did not verify the accuracy of exhaust flow rate measurement and CO_2 measurement using techniques such as carbon-balance versus ECU reported fuel rate data. Such verifications are assumed to have been done (by the manufacturer) before data is submitted to EPA since they are included in 40 CFR 1065 subpart J that manufacturers are required to meet."

The methods and procedures employed to convert source data to model input is appropriate and detailed. The reviewer would like some clarification in regards to the activity distribution of the data and the data binning approach used in the calculation. In specific:

The data obtained from the HDIUT testing will be primarily of long-haul truck operation characterized by predominant highway based operation. Although this might not affect emission rates of early model year vehicles, the use of this data could be biased towards high speed operation and lower NO_x emissions from SCR. Is there a distribution of what percentage of data from HDIU testing consists of low-speed transients?

Response: .The HDIUT data includes LHD, MHD, and HHD vehicles with a wide variety of operational conditions. In Section 2.1.1.1, we added this text and a citation to a conference presentation that includes information on time and NOx emissions by operating mode:

"The operational conditions include a wide range of driving speeds, transient and steady-state conditions, engine loads, and exhaust temperature conditions that have implications for emissions control efficacy, particularly for NO_x.[5] For the HHD class, out of a total 159 vehicles, 109 were line-haul, 46 were delivery, and the remaining were marked as "Other" in the metadata.

We also mention in this section:
We plan to expand the characterization of the MY 2010+ HDIUT data set, in a future update to the report, by adding summary information on vehicle age distribution, odometer reading, idling time duration, and operating mode based time

and miles travelled."

In this section the report does not adequately explain how the 1Hz or 5 Hz continuous data from the different sources are segregated into the different operating modes and emissions rates for the different operating modes are calculated. Is a moving average type binning method is applied?

> *Response: To determine the emission rate for an operating mode, each second of data is binned into its corresponding operating mode. No moving average binning method is applied. The method to determine emission rate per operating mode is described in Section 1.6 (Operating Modes) and Section 2.1.1.3 (Calculate of Operating Modes). We discuss the methods of averaging the second-by-second data by operating mode for each individual truck in Section 2.1.1.4 for 1960-2009 trucks, and in Section 2.1.1.5 for 2010-2060 trucks.*

Reviewer believes instantaneously assigning the emissions rate to different opmodes will lead to a lot of inaccuracies due to thermal inertia of aftertreatment systems, inaccuracies in broad cast torque of ECU, time alignment errors etc.

> *Response: We do not view the variations in operating mode-based emission rates as inaccuracies, but rather variations that we want to capture. We do realize that history effects will impact the results, therefore, we attempt to include the largest set of data available to capture these effects. Thus, for example, the emission rate for OpMode 35 is meant to be the average rate that is representative of the variety of operational conditions seen in the real-world, including instances when the SCR aftertreatment was hot (low NO_x rate) or cold (high NO_x rate). The HDIUT data is required to be gathered in compliance with the requirements in 40 CFR 1065 Subpart J, which minimizes the inaccuracies of ECU reported engine torque and requires time alignment. We believe any remaining errors have a small effect on the OpMode-based emission rate when it is based on the average of a large sample, as is the case with the HDIUT data set.*

Section 2.1.1.4.1 Hole-filling Missing Operating Modes

Figure 2-3 shows the missing real-world data in the different operating modes

The figure supports the fact that the opmodes 29, 30, 39, and 40 fall in the ranges that are beyond the power rating of most HD trucks. Also the speed combination of greater than 50 and between 25 and 50 at those high operating modes is probably not possible for a fully loaded truck at 80,000 lbs. Even if there is an engine rating that can deliver that high engine power, the operation has to occur on a positive grade, and during this operation the vehicle cannot physically reach those speed bins. Should the EPA consider eliminating those speed bins, since they are not physically possible? Or is there any data to indicate otherwise to have those bins for HD application.

> *Response: The operating mode modal model for heavy-duty uses a fixed mass factor, called f_{scale}, and the binning is based on a scaled power-demand concept. To address the problem cited by the reviewer, we have adopted new f_{scale} values such that all the*

operating mode bins, including those mentioned by the reviewer, are populated by real-world data. The method to decide new f_{scale} values is described in Appendix G of the MOVES3heavy-duty report, which includes updated figures that replaced Figure 2-3 in the draft report.

Figure 2-10 accurately represents the decreasing emissions rate with newer model year group.

Does the projection from 2013-2050 assume no change to emissions standard?

Response: We have updated Figure 2-20 from the draft report with Figure 2-18 and Figure 2-19 in the MOVES3 report. Figure 2-19 shows the projected g/mile emissions estimated from MY 2007 and later vehicles. We added text to the text proceeding Figure 2-18 to describe reasons for the change in g/mile emission rates, even though the operating mode-specific rates for most heavy-duty diesel vehicles do not vary from MY 2018 forward.

MOVES incorporates differences in the MY 2010-2018 emission rates due to manufacturers certifying engines above 0.2 g/bhp-hr which is allowed due to emissions averaging, banking, and trading, and use of nonconformance engines. The production volume of the engines by NOx certification level, and averaging method is documented in Section 2.1.1.5.

Post 2007 PM emissions from DPF equipped vehicles are below detection limits. Tampering and mal-maintenance adjustments seem appropriate. However, the report does not seem to address data related to DPF malfunctions or failures. Can data from manufacturers shed light on the level of DPF malfunction due to various engine related faults such as stuck EGR valves, injector failure, turbo failure etc. These types of failures are common, and although there is not enough published literature related to these, manufacturer warranty claims should suggest rates of failure. The reviewer believes, engine related DPF failure events could be more common that tampering or malmaintenance.

Response: ARB's data on T&M is incorporated in the model, as shown in Appendix B, and includes DPF failures. We plan to update the effects of these factors in the future as more data becomes available.

The EC and OC fraction of PM from pre and post 2007 model year vehicles are accurately represented. The report suggests that bulk of the EC/non-ECPM data was obtained from the ACES study. This study could be representative of just one engine model and the cycle used in this work was an extended 16 hr long cycle. Reviewer believes that the EPA should consider the use of data from chassis dynamometer testing from a wide range of drive cycles to compare the results obtained from the ACES study.

Unregulated greenhouse gas and ammonia emissions from current technology heavy-duty vehicles, Arvind Thiruvengadam, Marc Besch, Daniel Carder, Adewale Oshinuga, Randall Pasek, Henry Hogo & Mridul Gautam, Journal of the Air & Waste Management Association Vol. 66 , Iss. 11,2016

Response: We have clarified in Section 2.1.2.1.8 that the ACES Phase 1 study is based on the testing of four engines. We also added this text to Appendix E.3 of the MOVES3 speciation report, where the derivation of the $PM_{2.5}$ speciation values are documented: The ACES Phase 1 derived EC fraction of 9.9% falls within the range of EC fraction of total carbon emissions (2 to 20%) reported from Thiruvengadam et al. 2016.[6]

Page 51: HC and CO emissions from 2010 and beyond base rates: The report suggests that the quality of HC and CO are not applicable here because instruments conform to requirements of 40 CFR part 1065. The measurement of HC with a FID detector has been standard and based on the reviewer's experience there hasn't been quality issues associated with FID measurement. However, one the frequently observed issues with PEMS measurement is related to CO. The use of a single cell NDIR for both CO and CO2 causes severe drifts in the analyzer during the test period. However, during the zero and span check the drift is nonexistent due to the use of dry calibration gas and zero gas. This drift readings have resulted in high CO emissions. Since, the standard for CO is high, and the focus has always been on NO_x, the results of CO and issues related to the measurement of it using PEMS has been rarely documented.

Response:

We added the Figure 2-42, which shows the g/mile CO emission rates for each regulatory class across model years, which shows the MY 2010+ emission rates are higher than the 2007-2009 emission rates, however, the 2007-2009 CO emission rates are not based on measurements.

We added this text to Section 2.1.3.2:
"for CO, the HHD rates for MY 2010+ are significantly higher compared to MY 2007-2009, but are comparable to the pre-2007 data which are based on emission measurements."

"In the 2017 review of a draft version of this report,[11] *we received a comment that single-cell-NDIR-based CO measurements suffer from severe drift that is not corrected by zero and span checks because the calibration gases are dry, while vehicle tailpipe exhaust gases are not dry. Based on the HDIUT data, it is not possible for us to determine if MY 2010+ CO emission rates are affected by the alleged drift in the CO measurements. We looked at the CO emissions for each of 93 vehicles in the HHD 0.20 FEL group (from the 2010-2016 selection years) and confirmed the high average CO rate is not due to a few outliers. Further, the CO emission rate for the MHD and LHD vehicles is significantly lower (see Figure 2-42). Based on the available data and trends, we are unable to confirm whether or not the high CO emissions for the HHD vehicles is real or an artifact of CO sensor drift. In Section 2.1.5, we demonstrated that the fleet-average heavy-duty CO emission rate estimates from MOVES compare well with measurements from heavy-duty exhaust plume capture and tunnel measurement campaigns conducted in 2015 and 2017, which increased our confidence that the CO emission rates measured from HDIUT are reasonable. Thus, we decided to accept the reported HDIU CO emission rates as valid."*

Figure 2-21: The time-specific CO emissions rates seem to be very high. The report suggests that the figure includes the T&M effects, but the emission rates seem to be overestimated. The highest CO emissions form a post 2010 truck was observed from the non-SCR Navistar engine certified at 0.50 g/bhp-hr. The DOC is a robust aftertreatment system that shows little deterioration through the life of the engine. Furthermore, higher op-modes should technical show lower CO emissions due to *(sentence was truncated in the text received by EPA)*

See response to previous comment.

Section 2.1.4 Energy

Page 61 line 3:" Second, the truck weights and road load coefficients are updated to reflect lower vehicle weight…."

It should be made clear in this sentence that the "lower vehicle weight" is lowering of curb weight of truck and trailer by using light weight material. The sentence reads like that trucks will carrying lesser payload.

Response: We clarified the text as suggested by the reviewer in Section 2.1.4.3.1 "Second, the truck weights and road-load coefficients are updated to reflect the lower vehicle curb weights through lightweighting of materials, lower resistance tires, and improved aerodynamics of the vehicle chassis."

Table 2-21. Does the table represent the energy consumption reduction from the engine alone or a diesel engine+chassis+trailer combination?

Response: The reductions in the table (now Table 2-25) result from a combination of improvements to the engine and other improvements outside of aerodynamics and tire rolling resistance. We added text following Table 2-25 to clarify this: "The reductions shown in Table 2-25 are a combination of improvements to the engine and other systems excluding aerodynamics and tire rolling resistances. The projected improvements due to aerodynamics and tire rolling resistance are reflected in new road load coefficients, as described in the Population and Activity Report."

In the study conducted by WVU and a report published by ICCT it is projected that by employing various engine based technology pathways HD engine will have a maximum fuel consumption reduction of 7.9% and 18.3% for the 2017 and 2020+ model years respectively. MHD will have a 10.6% and 19.5% reduction in fuel consumption for 2017 and 2020+ model years respectively.

http://www.theicct.org/sites/default/files/publications/HDV_engine-efficiency-eval_WVUrpt_oct2014.pdf

The numbers in table 2-21 corroborates this projection. However, if the vehicle improvements are factored, then the projections in WVU study could be more.

Response: Our projections for future energy rates are based on manufacturers meeting the Heavy-Duty GHG Phase 1 and Phase 2 standards, not exceeding them. We will continue to refine the energy rates in the future with actual data.

Section 2.2 Start Exhaust Emissions

The report does not clearly explain the definition of a fully warmed engine (is it just engine orengine and aftertreatment system). Also since the start emissions is a function of soak, what portion of the operation after the start is "start emissions"?

Response: Start emissions represent the emissions that occur after the vehicle is started but before the engine and aftertreatment are fully warmed up. There are a variety of accepted ways to define start emissions, including the stabilization of engine coolant temperature or the achievement of a minimum aftertreatment temperature. Each manufacturer has a different control strategy for managing start emissions and the time it takes to achieve fully warm operation depends on operating conditions and drive cycle. We added discussion and equations in Section 1.2.2 to define how starts are defined for heavy-duty vehicles in MOVES as the increase in emissions due to an engine start after the vehicle or engine has soaked for a minimum of 12 hours. Operationally, we use the difference in emissions between a test cycle with a cold start and the same cycle in fully warm operation with a hot start. In practice, the warm cycle often includes a hot start, however, we assume the hot start has a negligible influence on the difference between the cold cycle and warm cycle.

2.2.1.1: The report suggests no data available for HHD or MHD trucks for the start emissions. Can data from the OEMS and other research labs that perform FTP certification testing fill this gap? The first 100-200 seconds of the cold FTP will provide the start exhaust emissions for engines. Also, the cold start of an SET engine dynamometer cycle will provide the start idle emissions for pre-2010 model year engines. Although the duration of the start exhaust emissions would be small, it would give an understanding of the magnitude of emissions rate and the duration of engine warmup.

Response: As noted in Section 2.2.1.2 of the MOVES3 heavy-duty report, HD engine manufacturers started to report as part of their application for certification to EPA the FTP results for the cold start and warm start separately in 2016, before that time they only reported the composite result. For the post-2010 model year engines, we used this data to update the start emission rates. Because we did not have data on older model year engines, updating the start emission rates for pre-2010 engines were outside the scope of the update for MOVES3.

2.2.1.2: Is there a reference to the use of equation 2-24? Warm engine is defined as the opening of the thermostat, which corresponds to a certain coolant temperature. An integration of emissions until a coolant temperature that corresponds to the initial opening of the thermostat could be a better estimation of start emissions.

Data set from a CARB and SCAQMD funded project, published in the journal paper by Quiros et al. could provide real-world start emissions data from post MY 2013 HDD.

Response: As noted in the responses above, EPA defines start emissions as the difference in emissions between a test cycle with a cold start (at least 12 hours of soak time) and a warm start for the MOVES model. Start emissions in MOVES are modeled as an additive number of grams of emissions per vehicle start. Because the emission data over the FTP cycle is provided in terms of grams per brake horsepower-hour (g/bhp-hr), the equation (now Equation 2-26) converts emissions from units of g/bhp-hr to grams. With respect to the suggested dataset from CARB and SCAQMD, we appreciate the suggestion, but after a review of the paper, we determined that we would not be able to determine the start emissions in a consistent manner with the FTP results that were used for the update.

The reviewer believes that the method for estimation of start emissions can be revised. Inferring it from FTP data is not sufficient for actual start emissions characterization. In the real-world it is observed that, irrespective of soak time, the warmup period of engine and aftertreatment system is fairly quick and the negative impact on emissions is greatly reduced.

Response: As noted in the previous responses, we agree that there are several methods to determine start emissions. By using the approach we have chosen, we capture the total emissions due to a cold start regardless of whether the warmup period for a specific engine is fairly quick or not. If a manufacturer's control strategy leads to a quick warmup, then the difference in emissions will likely be small and that data is included in our analysis.

Section 2.2.4 Start Energy Rates

Since fleet fuel consumption plays an important role in the HDD market, manufacturers mostly employ rapid engine warmup procedure to reduce fuel consumption. Intake throttling, higher fueling and intake manifold heating are some of the strategies that maybe used during start. The report correctly identifies that the fraction of start energy is very little compared to the total energy used by HDD, however it is also to be noted that significant auxiliary power loading can take place after a long start. Air compressor and alternator loading can be higher, particularly for applications such as urban bus. Data from OEM can shed light on the warm-up strategies employed and the energy consumption.

Response: We agree that manufacturers have a strong incentive to both minimize fuel consumption and control emissions during the engine warmup. The use of FTP data to determine the start emissions takes into account the reviewer's concern about considering OEM's warmup strategies. EPA accounts for the auxiliary power load impacts of items such as the alternator and air compressor in MOVES separately, as described in Section 2.1.1.3.

Section 2.3.2 Extended Idling

Figure 2-46. Trucks certified to operate or idle in California must either be enabled with 5 minute auto idle shut-off or conform to the 30 g/hr optional idle NO_x standard. The time-specific emissions rate shown in figure 2-46 show a small fraction of trucks with idle emissions at or below the 30 g/hr NO_x.

Response: We assume that the author is referring to Figure 2-56 in the draft report, *which is Figure 2-68 in the MOVES3 heavy-duty report. The extended idle NOx emissions depend on the ambient temperature, engine speed, and auxiliary loads experienced by the engine. As shown in the figure (Figure 2-68) under lab conditions, the NOx emissions for 2010 MY and later were approximately 30 grams per hour. However, the engine often idles at higher revolutions per minute and higher load settings when the operator requests heating and/or cooling which leads to higher NOx emissions.*

Page 95 Line 16: The assumption of trucks under warranty will have substantially fewer aftertreatment failures need to be revisited. DPF failures do not occur because of faulty aftertreatment system. A combination of engine control system failure leads to DPF failure. Frequently a stuck EGR valve causes increased soot loading leading to DPF failure. The OBD strategies in most cases do not pick up failed DPF or other system failures. Warranty data presented by David Quiros by ARB in CRC real-world workshop should shed light on DPF failure rates.

Response: In MOVES, we assume that more failures will be fixed and fixed sooner and therefore will have a lower emissions impact while the engine/aftertreatment is under warranty and the repair costs are covered by the manufacturer. Later in the vehicle's life when it is no longer under warranty, the operator may have less incentive to repair issues that do not affect performance of the vehicle. EPA agrees with the reviewer that additional data should be considered and we will conduct updates to tampering and malmaintenance in future MOVES releases as additional data becomes available.

Section 4 Heavy-Duty Compressed Natural Gas Emissions

The reviewer believes that the contribution of refuse trucks would be similar to that of transit buses fueled by CNG. These two captive fleets are largest in CNG usage in California.

Response: We added Figure 4-1 to display the CNG penetration among heavy-duty source types in MOVES using vehicle registration data, which shows the highest penetration among refuse trucks.

We also added the following sentences:
Fleet vehicles are operated as back-to-base, which means the vehicles return to the same base location each day for refueling. Within this segment, some of the most prevalent use of in CNG vehicles has occurred among city transit bus fleets and in solid waste collection or refuse truck fleets.[7] Figure 4-1 displays the fraction of heavy-duty CNG fueled-vehicles by source type and model year estimated in the default national activity database in MOVES3."

Table 4-1: Is there a reason has listed only literature pertaining to pre-2007 CNG transit buses.

Below studies funded by CARB and SCAQMD shows emissions rate from newer natural gas transit buses

Criteria pollutant and greenhouse gas emissions from CNG transit buses equipped with three-way catalysts compared to lean-burn engines and oxidation catalyst technologies, Seungju Yoon, John Collins, Arvind Thiruvengadam, Mridul Gautam, Jorn Herner & Alberto Ayala, Journal of the Air & Waste Management Association Vol. 63, Iss. 8,2013

SCAQMD funded study conducted by WVU and UCR tested CNG transit buses over multiple driving cycles.

Response: Thank you for providing the additional sources. Table 4-1 documents the studies used in MOVES2014 (and MOVES3) to develop natural gas emission rates for the pre-2010 model year vehicles. We have reorganized the report, with this table and text now in Section 4.1.1 (1960-2009 Model Years) to clarify that the analysis in this section only applies to those model year vehicles.

Section 4.2.13 Table 4-2. For 2007-2009. Were there lean-burn NG engines certified above 0.20 g/bhp-hr during that time period. Cummins ISLG achieved 0.20 as early 2007?

Response: Yes, the 2007-2009 MY lean burn NG engines were certified to NOx levels above 0.20 g/bhp-hr. Manufacturers certified stoichiometric NG engines with 3-way catalysts both above and below 0.20 g/bhp-hr NOx, depending on the engine.[a] Also note that Table 4-2 is now in Section 4.1.1.2.3 of the MOVES3 heavy-duty report.

Specific Questions

1. ***[Section 2.1.1.3.2.] For a given regulatory class and NO_x FEL group, we did not distinguish emissions rates between model years. The currently available HDIU data set is limited to data from MY 2010-2013 engines. Are there any studies that show NO_x emissions of engine families, with similar NO_x FEL levels, have changed significantly in recent model years due to improvements in engine management or thermal management strategies or catalyst formation?***

2.1.1.3.2 The study by Quiros et al has limited data that supports the fact that since the inception of SCR control in 2010, significant advancements in thermal management, urea dosage strategy, SCR formulations have taken place. Real-world emissions rates have in general reduced since MY 2010. Although Quiros et al. discuss a very limited dataset, this CARB and SCAQMD funded study compared to other previous chassis dynamometer work, documented in (Thiruvengadam et al, Dixit et al.) has shown considerable reduction in NO_x emissions rate from MY 2013, and 2014 HD diesel engines.

Real-world emissions from modern heavy-duty diesel, natural gas, and hybrid diesel trucks operating along major California freight corridors. DC Quiros, A Thiruvengadam, S Pradhan, M Besch… -Emission Control Science and Technology, 2016

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[a] U.S. EPA. Annual Certification Data for Vehicles, Engines, and Equipment. See https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment

Emission rates of regulated pollutants from current technology heavy-duty diesel and natural gas goods movement vehicles. A Thiruvengadam, MC Besch, P Thiruvengadam… - Environmental science & technology, 2015

Poornima Dixit, J. Wayne Miller, David R. Cocker, Adewale Oshinuga, Yu Jiang, Thomas D. Durbin, Kent C. Johnson, Differences between emissions measured in urban driving and certification testing of heavy-duty diesel engines, In Atmospheric Environment, Volume 166, 2017, Pages 276-285, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2017.06.037.

Response: The focus of the initial MOVES update was to appropriately reflect the implementation of the 2007/2010 NO_x standards by the manufacturers and their use of engines certified to various family emission limit levels. The HDIUT data used in the analysis is predominantly MY 2010-2013 engine families, a handful of engine families from MY 2014, and even fewer from MY 2015. Due to the small number of MY 2014 and later engines, for the draft MOVES version used for the preliminary Cleaner Truck Initiative analysis we did not attempt to model differences in the emission rates of the 0.2 NOx FEL groups, and combined the MY 2010 and later vehicles only by NOx FEL group.

For MOVES3, we incorporated additional HDIUT data for MY 2013 through and MY 2016 vehicles in the analysis. Due in part to these comments, we developed separate emission for the MY 2010-2013 and MY 2014 -2016 vehicles within the 0.2 NOx FEL group. We did not have sufficient data or reason to suspect significant differences would occur for the vehicles in the 0.35 and 0.5 NOx FEL groups by model year. We added additional rationale and comparisons of the emission rates for the 0.2 NOx FEL group by regulatory class in a new Section 2.1.1.5.2 in the MOVES3. We added the following text, that includes the cited references:

"We grouped the vehicles within the 0.2 NO_x FEL Group further into 2010-2013 and 2014 and later model year groups to account for differences in emissions performance of more recent engines and aftertreatment systems. Both of the 2017 peer-reviewers recommended that MOVES3 consider varying emission rates by model year for MY 2010 and later trucks, citing studies[8,9,10] that supported the claim that "since the inception of SCR control in 2010, significant advancements in thermal management, urea dosage strategy, and SCR formulations have taken place." [11] [11] For MOVES3, we were able to incorporate data from MY 2014-2016 engines to evaluate this recommendation."

2. ***[2.1.1.2, and 2.1.1.4.1] EPA is considering updating the fixed mass factor (f_{scale}) values for heavy-duty vehicles (regClassID 40 through 48). The details are provided in Appendix 2 of this charge letter. What might be a better method to estimate an appropriate fixed mass factor for each regClassID? In addressing this question, you may find the background information on the f_{scale} discussed in Section 1.3, pertinent to this question.***

2.1.1.2 and 2.1.1.4.1: The current fscale of 17.1 results in STP values significantly higher than the maximum engine rating available in the HD segment. The reviewer believes that the fsacle can be chosen that the maximum tractive power is always less than the average maximum available power rating of all the engine models. This would also be able to fill some of the high power opmodes of downsized engines working at full load. Fscale could be calculated as a linear fit between vehicle power and CO_2 emissions should provide a better estimate of fscale relevant to each regulatory category.

Response: We used an empirical method that used the HDIUT data set to select more appropriate fscale values for each of the HD regClasses for MY 2010+. This method assured that we had sufficient data from the HDIUT to estimate each of the operating modes. The method and results are now described in Appendix G.

3. ***[Section 2.1.2.2.6] For MY 2010+ PM rates, we initially decided not to use the HDIUT data because the numbers were scarce or low, raising concerns about the quality of the data. Since the trends look fine we would like feedback on whether the HDIUT PM rates are of expected magnitude. Additional details are provided in Appendix 3 of this charge letter.***

2.1.2.2.6 The PM data from the HDIUT program would be primarily in the NTE region. Depending on the type of PM PEMS employed the variation in PM measurement could be significant. Since, both gravimetric and the PM sensor measure below detection limit, the use of in-use PM emissions rate must be avoided.

Figure 3 in attachment B shows an appropriate trend with slightly increasing PM concentrations at higher load opmodes. This has been observed in many in-use studies and can be attributed to the slight drop in filtration efficiency due to the passive regeneration of DPF at high exhaust temperatures.

For the post 2007 engines, the use of the AVL soot sensor data could be useful to update PM numbers at a higher confidence level. Although the soot sensor only records soot mass, this would still account for bulk of PM emissions and even marginal drop in filtration efficiency.

Response: We used the PM emissions data from the HDIUT data set to update the PM rates. Our confidence in the data was increased by comparing the PM rates estimated from the HDIU data set (many of which are measured using an AVL Micro Soot Sensor), as discussed in the following text added to Section 2.1.2.2.1.

"Because much of the HDIUT PM data are missing or reported as zero, and given the additional uncertainty regarding the MHD rates, we compared our HDIUT-based $PM_{2.5}$ rates against values reported in the literature. As shown in Figure 2-28, the MOVES age 0-3 $PM_{2.5}$ rate ranges from 3 to 26 mg/mile for a MY 2010-2014 HD vehicle and from 2 to 7 mg/mile for MY 2014+. Other studies have reported $PM_{2.5}$ rates in the range of 1-7 mg/mi for MY 2010+ vehicles equipped with DPF and SCR and certified to NO_x standard of 0.20 g/bhp-hr.[8,9,10] The rates from the MOVES run

and other studies are dependent on driving cycle; however, since the MOVES rates are generally within the range of reported values, we believe it is reasonable to use the HDIUT-based $PM_{2.5}$ data for the update for all regulatory classes."

Please see the comments regarding DPF regeneration in our response to Dr. Zietsman below.

We acknowledge the challenges in measuring PM emissions during in-use testing for vehicles with high efficiency DPF filters. EPA is continuing to increase our capability to measure second-by-second PM data which will help inform future MOVES updates.

4. ***[Section 2.3.1.] We generated our pre-2007 NO_x, HC, and CO extended idle emissions rates assuming 33% of trucks idle at 1000 RPM or higher engine speeds during extended idle. Can the reviewers recommend better sources or techniques for estimating the prevalence of "high idle" during extended idling?***

Section 2.3.1: The data collected by EPA for extended idling emissions seems to be comprehensive. The practice of using high idle is very subjective and depends on the truck driver and their practices. There is increase in idle speed as hoteling loads are added to the engine, and this may result in engine rpm going up to 1000 rpm. The best method to establish the practice of using high idle would be to conduct a survey of fleets. Also, telemetry based data collection (PAMS) can also shed light on the percentage of time high idle is being used.

In the case of vehicles equipped with auto idle shut-off, reviewer believes the high idle switch disables the auto-idle shut-off and hence could prompt drivers to use it more often.

Response: Thank you for sharing your suggestions and observations.

With regard to using telemetry, we could evaluate the frequency of high engine idle in the NREL Fleet DNA database. However, that may not provide a representative estimate of high idling for pre-2007 MY trucks. We do not have the model year for most of the long-haul trucks in the evaluated FleetDNA data for MOVES3. As discussed in the MOVES3 heavy-duty report, high idle was observed to be more prevalent in the pre-2007 heavy-duty diesel vehicles (Section 2.3.1). However, for the MY 2007+heavy-duty vehicles there appears to be much less use of high idle for extended idling as discussed in (Section 2.3.2). Most of the trucks did not high idle during the extreme extended idling condition, and 6 of the 15 trucks were unable to be commanded to high idle.

Currently, we do not plan to conduct fleet surveys or initiate new PAMS-based data collection to supplement our existing data, but will continue to follow others' vehicle data collection efforts to identify candidate datasets to update future MOVES versions.

5. ***[Section 2.3.1.] We assume MHD (regClassID 46) and HHD (regClassID 47) combination long-haul trucks have the same extended idle emission rates. Do the reviewers agree? Or can they point to sources that suggest different emission rates based on engine size?***

Section 2.3.1 Reviewer believes that the extended idle emissions rate will be different for MHD and HHD due to the engine size difference and the thermal inertias associated with the engine and aftertreatment system. The HDIUT program from OEM should have sufficient data characterizing extended idling from MHD. One of the main differences in a MHD idle activity is that, in general MHD are used for short delivery applications and do not necessarily idle like a HHD vehicle.

Response: While we agree that there will be some emissions rate differences between MHD and HHD, but we do not have a reliable source for MHD extended idle rates. EPA's manufacturer-run in-use testing program does not include sufficient extended idle data for the MHD vehicles tested.

Also note, that the "short delivery applications," cited by the reviewer would typically be classified in MOVES as "off-network idle" rather than as "extended idle" and would not contribute to MHD-HHD differences in extended idle emissions.

Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X

General Questions

Section 3: Humidity Adjustments

The report indicates that MOVES applies the humidity correction factor to all base exhaust emissions. When EPA receives data from the different sources, is the uncorrected NOx values used or is the corrected NOx values used. If the data source already performed the humidity correction (which is standard procedure according 40 CFR Part 1065) then the MOVES calculation will be double correcting it. The reviewer believes there is more info needed about how source data is processed. When our research group provides data for modeling, we provide the humidity corrected data.

Response: As stated in the beginning of the document, we did not incorporate the proposed humidity adjustments into MOVES_CTI_NPRM or MOVES3, because the updates required a coding change that we were not able to make within the timing constraints for those MOVES versions. We continue to use the humidity adjustments as were used in MOVES2014b.

In response to the comments, we clarified in Section 3 of the MOVES3 adjustment report that the emissions data that we used to develop emission rates are adjusted from the test conditions to the standard humidity level. In MOVES, we adjust the *base emission rates to the humidity level specified in the run spec. As discussed in Section 3.1, MOVES uses the inverse of the humidity equation used to adjust the emissions data from the standard humidity level to the humidity level specified in the run spec.*

Because we are using the inverse of the humidity correction factor, we are not double correcting for humidity, but are "uncorrecting" the NOx emission rate to match the ambient humidity level specified in the run spec.

Specific Questions

1. ***[With respect to Section 3.2]: Are you aware of any studies examining the effect of intake air humidity on tailpipe NO_X for model year 2010 and beyond heavy-duty engines/vehicles?***

The reviewer is not aware of any study that was aimed at studying the effect of intake air humidity on tailpipe emissions of NOx from modern HDD engines/vehicles. However, this information can be extracted from any real-world testing exercise or PEMS measurement project. Few of the studies are noted below. SCAQMD and CARB funded study on 7 HD trucks in California has vast amount of data that can provide accurate links between ambient humidity and tailpipe NOx emissions from both modern HDD and HD CNG trucks.

Using raw NOx data uncorrected for humidity from the HDIU data and plotting tailpipe NOx emissions against ambient humidity should also provide an excellent dataset to examine the effect of intake air humidity on tailpipe NOx emissions. In-use emissions testing work performed by CARB on heavy-duty refuse trucks in Sacramento, CA will also provide an excellent dataset for analyzing humidity effects. Results from this work was published by

Misra et al.In-Use NOx Emissions from Diesel and Liquefied Natural Gas Refuse Trucks Equipped with SCR and TWC, Respectively, Chandan Misra, Chris Ruehl, John Collins, Don Chernich, and Jorn Herner, *Environmental Science & Technology* **2017** *51* (12), 6981-6989, DOI: 10.1021/acs.est.6b03218

Response: Thank you for the suggested studies. We mention in the MOVES3 adjustment report that we recommend future research to evaluate humidity correction including using in-use emission testing and modern vehicles. One difficulty of using in-use data are the confounding effects of vehicle operation and ambient conditions.

Comments from Josia Zietsman Ph.D., P.E.

Dr. Zietsman peer-reviewed sections of the reports in September 2017 according to the charge outlined in the previous section. At the time of the review, Dr. Zietsman was the Division Head and Senior Research Engineer with the Environment and Air Quality Division with the Texas A&M Transportation Institute and the Texas A&M University System. Dr. Zietsman's comments are unedited, but formatted to be consistent with the format of this report. EPA responses to the comments are in italic.

Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES201X

General Questions

The MOVES model is comprehensive and the proposed changes/updates to the HDDV onroad emission rates will result in an improvement to the current version. In general, the report does a good job of describing the data and assumptions, and did a good job in using the best available methodologies. However, there are certain areas where additional clarity can be provided and methods can be improved, as noted below and in response to the specific questions.

Section 2.1 Heavy-Duty Vehicle Emissions

Section 2.1.1.1 – In the description of data collected through the various initiatives it is not clear which one collected data for buses even though Table 2.2 shows that some bus data was collected.

> *Response: The ROVER test program included both buses and trucks. We say this in the main text, "The data we used represents approximately 1,400 hours of operation by 124 trucks and buses of model years 1999 through 2007."*

Section 2.1.1.2 – the power loss assumptions, as noted, is not very data driven. Can some measurements be implemented (at the axle, for example) to validate the assumptions or to potentially replace the need for calculating the losses.

> *Response: We acknowledge the need to conduct future work to improve the estimates currently in MOVES. We added this text in this section (now Section 2.1.1.3): " It is possible that future test programs might acquire accessory load information from the ECU and axle efficiency data is available through certification information during the HD GHG Phase 2 compliance program."*

Section 2.1.1.3.2 (Pg 20) – Creation of NOx FEL groups – a table will help in clarify of the information with regards to FEL groupings.

> *Response: We substituted the bulleted list with a table showing the FEL groupings. See Table 2-6 within this section (now Section 2.1.1.5.1)*

Section 2.1.1.8 – In discussing Sample Results one wonders about the effect of alternative fuels such as CNG and biodiesel as well as electrification moving forward.

Response: As discussed in Section 4, we describe the MOVES updates to heavy-duty natural gas emission rates and vehicle categories. We will continue to monitor the evolution of the electrification in the heavy-duty sector and consider the appropriate updates to future versions of MOVES.

We are interested in additional data on biodiesel impacts on heavy-duty emissions. MOVES only include biodiesel effects on THC, CO, or NOx for pre-2007 MY vehicles as discussed in the MOVES fuel effects report.[12]

Section 2.2 Start Exhaust Emissions

Section 2.2.1.1 – it is mentioned that no temperature adjustments are applied to CO, PM or NOx diesel start emissions. It is warranted to state why that is the case. Likely because the effect is much greater on HC.

Response: As discussed in Section 2.4 of the MOVES3 emission adjustment report, the emissions data for pre-2007 light-duty diesel only showed a clear trend of THC emissions with ambient temperature. No clear trend was observed for CO or NOx. Also as stated in Section 2.4. of the MOVES emissions adjustment report regarding PM effects:

"The reviewed studies suggest that temperature does influence cold start PM emissions from diesel vehicles. However, at this time, MOVES does not include temperature adjustments to diesel start emissions due to limited data on diesel engines and because diesel starts are a minor contributor to particulate mass emissions to the mobile-source emission inventory. The diesel particulate matter emission temperature effects in MOVES can be revisited in the future as additional data become available."

Section 2.2.3.1. (Pg 73) – add explanation for why the base cold start emissions rates are zero for NO_x and HC

Response: In Section 2.2.1.1, we discuss the data used to derive the base cold start emission rates for pre-2010 model year engines. The data supports zero start emissions for both NOx and THC. We added a cross-reference pointing to Section 2.2.1.1. The sentence reads:
"For medium and heavy heavy-duty vehicles (regulatory classes MHD, HHD, and Urban Bus) only the CO soak fractions are applied to the cold-start emissions, because the base cold start THC and NO_x emission rates for medium and heavy heavy-duty emission rates are zero (see Section 2.2.1.1)."

Section 2.2.3.2 – It is stated that the emission reduction report discusses the impact of temperature on cold start emission rates for opMode 108. Why is this effect not included?

> *Response: We clarified in Section 2.2.3.3 that the ambient temperatures effects are applied to starts of all soak lengths. The temperature effect for opMode 108 is included in Table 2-42.*

Section 2.3.2 Extended Idling

Section 2.3.1 (Pg 86) – why the large increase in NO_x extended idle emissions rate between pre-1990 and 1990-2006 MYs?

> *Response: We do not have a technical explanation apart from what the available data indicates, as shown in Appendix D.*

Specific Questions

1. ***[Section 2.1.1.3.2.] For a given regulatory class and NO_x FEL group, we did not distinguish emissions rates between model years. The currently available HDIU data set is limited to data from MY 2010-2013 engines. Are there any studies that show NO_x emissions of engine families, with similar NO_x FEL levels, have changed significantly in recent model years due to improvements in engine management or thermal management strategies or catalyst formation?***

The current approach of not distinguishing emissions rates between MYs in a regulatory class seems reasonable, however, it is clear that more in-depth testing and research needs to be done. For example, a pair of studies performed by TTI using the on–road heavy duty measurement system (OHMS) showed high levels of NO_x for newer model trucks, likely linked to SCR functionality/exhaust temperature – reports available here: http://www.nctcog.org/trans/air/hevp/DieselIM/. A couple of other studies also showing NO_x emissions differences between vehicles of same type with slight different MYs include:

1. Kotz, A.J., Kittelson, D.B., Northrop, W.F. et al. Emiss. Control Sci. Technol. (2017) 3: 153. https://doi.org/10.1007/s40825-017-0064-4 (for buses)

2. In-Use NO_x Emissions from Model Year 2010 and 2011 Heavy-Duty Diesel Engines Equipped with Aftertreatment Devices, Chandan Misra, John F. Collins, Jorn D. Herner, Todd Sax, Mohan Krishnamurthy, Wayne Sobieralski, Mark Burntizki, and Don Chernich. Environmental Science & Technology 2013 47 (14), 7892-7898, DOI: https://doi.org/10.1021/es4006288

> *Response: Thank you for sharing the references of studies on the emission performance of SCR equipped diesel trucks. See our response to this question from Dr. Thiruvengadam above.*

2. ***[2.1.1.2, and 2.1.1.4.1] EPA is considering updating the fixed mass factor (f_{scale}) values for heavy-duty vehicles (regClassID 40 through 48). The details are provided in Appendix 2 of this charge letter. What might be a better method to estimate an appropriate fixed mass factor for each regClassID? In addressing this question, you may find the background information on the f_{scale} discussed in Section 1.3, pertinent to this question.***

In my opinion, a focused research project collecting empirical data would be useful, to revisit the concept of a fixed mass factor, or to provide some form of benchmarking or possible linkage to physical characteristics of the vehicle and engine. Given that the fixed mass factor is a scaling constant without any physical/dimensional properties, the selection of the number can be viewed as arbitrary and open to potential scrutiny or even lawsuits. An analogy for this "revised" factor would be something like the Reynolds number.

A further point to consider is the probability of vehicles actually operating in the extreme operating modes that currently do not have data in them. More empirical data collection can be used to verify this.

Response: We used an empirical method that used the HDIUT data set to select more appropriate f_{scale} values for each of the HD regulatory classes for MY 2010+. This method assured that we had sufficient data from the HDIUT to estimate each of the operating modes. The method and results are described in Appendix G.

The values represent a balance between covering the entire operating modes of vehicle activity and having sufficient emissions data to develop the emission rate for each operating mode. In our reasoning we explain how the new fscale values allow the highest power operating mode to accommodate vehicles operating under extreme loads. In our current data sets, we do not have sufficient emissions data for extreme load conditions, so this is something we will continue to look out for as future improvement.

3. ***[With respect to Section 2.1.2.2.6]: For MY 2010+ PM rates, EPA initially decided not to use the HDIUT data because the numbers were scarce or low, raising concerns about the quality of the data. Since the trends look fine, EPA would like feedback on whether the HDIU PM rates are of expected magnitude. Additional details are provided in Attachment B of this Peer Review Charge.***

The order of magnitude of the numbers seem reasonable. The challenge is always measuring PM at such low levels, close to equipment detection limits. This is also noticed in the large error bars in the data, and there is a clear need for additional data collection for newer MYs and continuing the efforts to develop more accurate testing equipment. It is also not clear if effect of regeneration is included in the data and that needs to be clarified.

Response: The emission rates based on the MY 2010+ HDIUT data set includes DPF regeneration events. We acknowledge the need to improve the modeling to include *the impact of DPF regeneration. Currently, real world data on regeneration is sparse. We will continue to gather data and perform literature searches both on the emissions impact of regeneration and its frequency to inform future versions of MOVES. We added a new section, Section 2.1.2.2.3 (DPF Regeneration Events), which states:*

"The MOVES 3 emission rates include active DPF regeneration effects because the HDIUT data set includes active regeneration activity, but MOVES does not model active regeneration explicitly. To do this, we would like to have detailed information on the frequency and emission effect of real world regeneration events by operating mode and regulatory class. Until we have that kind of data and see a need for that detail in MOVES, we assume that the emission rates in MOVES for MY 2010+ HD vehicles reasonably capture the average effect of active DPF regeneration events."

"To assess the amount of active regeneration activity in the HDIUT data, we examined the ECU codes. Modern DPFs have catalyzed substrate that allow them to undergo passive regeneration when the vehicle is operating at high-speeds and/or high-loads such that the exhaust temperature is sufficient to induce the regeneration. The passive regeneration events are "silent" and happen in the background without any regeneration code in the ECU data. On the other hand, active regeneration events happen when the ECU actively raises the temperature in the exhaust so that the soot captured in the DPF can be combusted. One way to increase the temperature is to inject additional fuel which gets burned off and raises the temperature. These events can raise the $PM_{2.5}$ *concentrations considerably, but may only occur infrequently. We analyzed the "Regen_Signal" column in the quality-assured 1 hz emissions data files for 77 vehicles in the HHD 0.20* NO_x *FEL group to estimate the frequency and count of regeneration events. It is our understanding that the "Regen_Signal" flag only accounts for active regen events. There were 11 vehicles with the Regen_Signal set to "Y" and the regen events totaled 60,576 seconds, which is about 18% of the data from just those 11 vehicles and 3% of the data from all 77 vehicles. Future work could evaluate whether the active regeneration observed in the HDIUT data is consistent with other studies and whether the* $PM_{2.5}$ *second-by-second measurements accurately capture the elevated* $PM_{2.5}$ *concentrations that occur during active regeneration events.*[b]*"*

4. ***[With respect to Section 2.3.1]: EPA generated its pre-2007 NOX, HC, and CO extended idle emissions rates assuming 33% of trucks idle at 1000 RPM or higher engine speeds during extended idle. Can you recommend better sources or techniques for estimating the prevalence of "high idle" during extended idling?***

[b] As discussed in the MOVES speciation report**Error! Bookmark not defined.**, the $PM_{2.5}$ composition can change significantly during regeneration events. Second-by-second $PM_{2.5}$ measurements made with a photoacoustic or optical method are dependent on the properties of the $PM_{2.5}$ composition

Additional driver interviews are a possibility, especially since the UC-Davis study that the 33% number came from is now dated. Further, on-board diagnostic data extracted via data loggers would be a good source. Several large fleets are likely implementing these to collect a range of data, and companies also exist to provide tracking services to fleets, such as http://www.teletracnavman.com/

Response: Thank you for your suggestions. We agree that additional driver interviews and vehicle data collection would provide valuable insight, but we do not plan to initiate new efforts at this time. We recognize that the 2004 UC-Davis study is dated, but note that we applied it to pre-2007 emission rates, so it is likely representative of engines from that era.

5. ***[Also with respect to Section 2.3.1]: EPA assumes MHD (regClassID 46) and HHD (regClassID 47) combination long-haul trucks have the same extended idle emission rates. Do you agree? Or can you point to sources that suggest different emission rates based on engine size?***

We are aware of at least one study (performed by TTI) which looked at idle emissions from Class 4, 6 and 8 trucks. There were differences in emissions rates, and it warrants revisiting this assumption. Report - Characterization of Exhaust Emissions from Heavy-Duty Diesel Vehicles in the HGB Area – available at http://tti.tamu.edu/documents/0- 6237-1.pdf ; see graph on Page 48 as an example.

Response: Thank you for your suggestion. We evaluated the TTI study and found that the idle rates were gathered after 1 hour with low engine speeds and that varying emission rates were presented. There are differences between Class 6 and Class 8 rates, as expected. However, it did not appear that the City of Houston Class 6 trucks were representative of MHD trucks used in long-haul operation. For example, MOVES3 default data estimates that all long-haul trucks for MY 2008 and later are HHD trucks. We would anticipate that MHD trucks that are used in long-haul operation are most likely Class 7 engines (not Class 6) and that long-haul trucks would have higher auxiliary idling loads during extended idle operation, compared to the day truck that was tested from the City of Houston fleet. We have decided to leave the MHD extended idle emission rates equivalent to the HHD emissions. It's important to note that HHD engines are used in 95% or more of the long-haul vehicles (sourcetype 62) vehicles and any change to the MHD extended idle rates will have very little impact on the overall inventory.

Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X

Specific Questions

1. ***[With respect to Section 3.2]: Are you aware of any studies examining the effect of intake air humidity on tailpipe NO_X for model year 2010 and beyond heavy-duty engines/vehicles?***

I am not aware of any studies that are more recent/covering MY 2010 or later, agree as stated in Section 3.2 that this warrants investigation.

No Response Needed

References

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