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September 7, 2017

**Subject: WA 0-14: Peer Review of "Update of Speciation & Toxic
Emissions, and Particulate Matter Emissions from Gasoline LDVs"**

Dear Mr. Dassa:

Thank you for providing Ecoengineering, Inc. the opportunity to review this section of the MOVES model documentation. Attached with this document please find my comments, and the signed Conflict of Interest Form. I believe this concludes my responsibilities under this contract, but if you have any questions or changes needed to this submission, please let me know so I can make the modifications. As you know I will be on vacation after this week for several weeks so I ask that you let me know if you need anything as soon as possible.

I can be reached at (303)619-4346 or by email at ecoeng.yano@gmail.com,

Sincerely,

Janet Yanowitz, P.E., Ph.D.
Principal

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WA 0-14: Peer Review of "Update of Speciation & Toxic Emissions, and Particulate Matter Emissions from Gasoline LDVs"

General Comments

This update continues EPA's refinement of the MOVES model. Not only is the MOVES program used for airshed modeling, its documentation is used by many for determining the likely impacts of individual changes in fuel and vehicle technology and operation.

One ongoing concern is the lack of documentation on the accuracy of the various input values. Often parameters are presented with numerous significant digits, clearly far beyond the accuracy of the source data, if only because of the limited number of vehicles tested. I understand that there is little to be gained by truncating these values for the purposes of the model, but I would propose that in future work EPA consider procedures for estimating and presenting the uncertainty of each parameter. The model could then be tested with a range (say plus or minus one standard deviation) of potential values of each parameter to determine the parameters most in need of further refinement. More importantly, if the model is using values that are no more than guesses, then the results are similarly compromised and not appropriate as the basis for policy decisions. In order to maintain trust in the model it is necessary to ensure that all of the results are based on data that is adequate to determine the stated results. Finally, as I noted above, the documentation is frequently used independently of the model and an understanding of the uncertainty would be valuable for those purposes.

Another addition to allow better understanding of the model is to compare estimates from the most recent past model (MOVES2014) with the newly proposed estimates such as in Figure 2-29 in Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X. Before and after figures provide a ready way for readers to predict the impact of changes without needing to run the entire model or review past model documentation.

One general stylistic comment would be to include captions for tables and figures that provide a more complete explanation of the contents, particularly in the case of those figures/tables which are presenting an intermediate stage in the process of determining final emission rates. Figures/tables can readily be taken out of context and it should be made clear when further adjustments are still required. For example Figures 2-31 and 2-32 in Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X have similar captions and yet one has been adjusted for deterioration rate while the other has not.

Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES 201X

Chapter 3

Table 3-1. I appreciate this table for clarifying the meaning of these terms as they are used in the MOVES model. These terms are used elsewhere in the sections which I reviewed. Please ensure that wherever they are used they have the meaning listed in this table and I would suggest that you do not use other terms to mean the same thing. For example, Section 1.4 of Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X uses the terms HC and THC, I believe interchangeably, but it is not clear that either or both refer to FID-HC, as the term is used in this table. Similarly, the term VOC is used in Section 3.1.2 of Air Toxic Emissions from Onroad Vehicles in MOVES201X - please confirm that is calculated in this section as you do in this table: FID-HC minus methane, ethane and acetone. I ask this because I have seen many cases in the scientific literature in which VOCs are assumed to include every organic compound.

Table 3.2. Profile Nos. 8754, 8769, 8770, 8878, 8934 for evaporative emissions of ethanol containing fuels. I would expect that the NMOG/NMHC and VOC/NMHC ratios would change depending on the vapor pressure of the fuel. Assuming a fixed ethanol content, the vapor pressure of the ethanol is relatively constant and the vapor pressure of the blendstock changes. Thus at high vapor pressures I would expect relatively more THC in comparison to ethanol in the vapors. E85 and E70 evaporative emissions (Profile No. 8934) are also impacted by vapor pressure, although to a lesser extent because there is a smaller amount of hydrocarbon. The methods in SAE Paper No. 2007-01-4006 can be adapted to estimate the mole fraction of ethanol in the vapor phase, given the RVP and ethanol content of the blend.

Table 3.2 Profile Nos. 8870 and 8871 for the headspace of ethanol containing fuels. NMOG/NMHC and VOC/NMHC ratios of 1 implies that all of the organics in the headspace are hydrocarbon. However, according to the same paper cited above there is always at least some ethanol in the headspace.

Section 3.1.2.1, p. 17. You write "The NMOG/NMHC ratio we estimated was 1.0312...." Table 3-4 Profile No. 8756 has a NMOG/NMHC ratio of 1.038.

Chapter 4 (pp. 21 and 24)

No comment.

Section 5.1 (step 8, p. 33)

No comment.

Air Toxic Emissions from Onroad Vehicles in MOVES201X

3.1.2

Table 54. Here is an example where the number of significant digits is misleading. 0.0 is the value used for "not detected" in numerous places in the table. While reasonable for purposes of the model as there is no difference between 0.0 or 0.00000 as input to a computer, in this table it implies that the measurement was only made to a limit of detection of 10% (0.1) of the entire mass of VOC which I think is unlikely considering the other measurements. On the other hand, directly above the table you note that there is considerable measurement uncertainty - suggesting that it is the other measurements, taken in many cases to five digits past the decimal point (0.001%) that are not be trusted. You also note that the PAH emissions were uncorrected for background concentrations. Depending on the location of the test site these can be significant.

I can understand the EPA perspective that they are only inputting the most accurate number possible given the data available, but perhaps if the reader could evaluate the uncertainty, it would be clear whether projections based on these numbers were trustworthy and appropriate as the basis for policy decisions. If the results are not appropriate for policy decisions then they do not belong in the model.

3.2.2

Table 56 - same comment as above, plus recommend that you note that PAH/VOC is for the gas phase and PAH/OC2.5 is for the particulate phase.

Table 57 - same comment as for Table 54

3.3

Table 58 - same comment as for Table 54

Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X: Sections 1.4 and 2.2

Section 1.4

Throughout - the terms HC and THC are used, I believe interchangeably. If this is true I would suggest you use only one term and that it be however you refer to pollutantID1 for clarity.

1.4 - second paragraph - Excess fuel is not the only reason for "start emissions". Another reason for "start emissions" is the temperature of the catalytic converter. It does not work effectively until it heats up. To further explain why excess fuel leads to excess emissions you might wish to explain that the

catalytic converter is designed to operated optimally at stoichiometric air/fuel ratio. At the lower air/fuel ratio, the catalytic converter is less efficient at controlling HC and CO emissions.

Table 1-26 Suggest that you add the word "adjusted" to the title to clarify that it is not just Bag1-Bag3

Line 6 - how do you adapt MY 1994-1999 sample results when this section only goes to MY 1995?

Table 1-28 - Table 1-28 and Table 1-25 seem to be talking about cold start emissions for the same group of cars (MY 1995 and earlier). If so please add "MY 1995 and earlier" to the title of this table.

Table 1-28 - what I think you are saying here is that the cold start HC emissions after a 3 minute soak are 5.1% of the cold start emissions of 720 minute soak; and for an 18 minute soak the cold start emissions are roughly 26.9% of the cold start emissions of a 720 minute soak. In Equation 1-42 is based on the same relationship although only between the cold start emissions of a 10 minute soak and the 720 minute soak. Not sure if this is obvious so I show below how I get this by restating Equation 1-42 as follows:

Bag1 - total emissions after 720 minute soak

Bag3 - total emissions after 10 minute soak

and to this we add another variable: the unmeasured (i.e. hypothetical) emissions after a soak of 0 minutes - let's call this Bag0.

Cold Start Emissions = Bag1 - Bag0

Cold Start Emissions after 10 minute soak = Bag3-Bag0

$(\text{Bag1} - \text{Bag0}) = (\text{Bag1} - \text{Bag3}) / (1-A)$

$(1-A) * (\text{Bag1} - \text{Bag0}) = \text{Bag1} - \text{Bag3}$

$\text{Bag1} - \text{Bag0} - A(\text{Bag1} - \text{Bag0}) = \text{Bag1} - \text{Bag3}$

$A(\text{Bag1} - \text{Bag0}) = \text{Bag3} - \text{Bag0}$

$A(\text{Cold Start Emissions after 720 minute soak}) = \text{Cold Start Emissions after 10 minute soak}$

Table 1-25 says that for a catalyst equipped vehicle HC emissions after a 10 minute soak are 12.09% of those after the 720 minute soak, i.e. the "A" value is .1209. This is roughly what you would get interpolating between the values for the 3 and 18 minute soak in Table 1-28, in which the adjustment (A) values are 0.051 and 0.269, respectively. Similarly for CO. However it does not work for NOx: Table 1-28 the adjustment (A) values for cold start NOx emissions for 3 and 18 minute soaks are 0.093 and 0.347 but in Table 1-25 for a 10 minute soak the adjustment (A)

value is .39366. Perhaps there is an explanation for this discrepancy, however I think you need to explain and make sure you have calculated these values correctly.

Figure 1-43. It is interesting that NO_x emissions are highest for the cold starts after intermediate length soaks. The FTP includes one very long soak (i.e. the start of Bag 1) and one short soak (start of Bag 3). Thus it does not capture this effect of increased emissions in vehicle certification testing. If EPA finds that intermediate soaks are common and producing significant emissions, then it will need to consider including intermediate soaks in its standard certification test procedure as currently available sophisticated engine controls are capable of controlling operating conditions to minimize this issue. As long as intermediate soaks are not part of the test procedure, OEMs will have not have motivation to control these emissions.

Figures 1-43, 1-45 and 1-46. It does not appear that cold start conditions have plateaued at 720 minutes. In the future you will need to add longer cold soaks to the experimental test conditions.

1.4.3.2 Line 13. <https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm> has more accurate data on the average rate of mileage accumulation per vehicle. It is higher than 10,000 miles per year.

Section 2.2

2.2.1 Line 10-11. Add reference for the Kansas City study.

2.2.2 Lines 17-25 and Table 2-7. In Section 2.3.2 of Emission Adjustments for Temperature, Humidity, air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X you conclude that the "significant PM running temperature effect detected for Bag 2" in the LA92 test cycle is "due to the short duration and relatively mild accelerations of the cold-start phase of the LA92 cycle, which is only 310 seconds in length. We note that the PM temperature effect was much larger at the beginning of Bag 2 than at the end." This suggests that at least in cold temperatures there are "start emission" effects in Bag 2. Do you find that for the room temperature starts considered in this section that there is any difference between the start and the end of the cycle for the same operating modes? If some "start emission" effects spill over into Bag 2 in the LA92 test cycle, this would also suggest that the "start emission" effects measured as Bag 1 - Bag 3 would also be underestimated in LA92. Did you find any significant differences in the "start emissions" between FTP and LA92?

Table 2-9. Make it clear that the first row of numbers are superseded by the second row - perhaps call first row "unadjusted scaling factor from new data (Table 2-8)" and second row "scaling factor from new data adjusted based on additional historical data"

2.2.6.2 Line 26 - you refer to "the combined curves", however the description above refers only to the sigmoid fit curve to the original data. Please describe how the other curve was generated.

2.2.6.3 Equation 2-7 This equation for the entire fleet needs to be changed to account for the different scaling parameters and different populations of LDVs and LDTs.

Figures 2-26, 2-27, 2-28 and 2-31 - Suggest adding "-not adjusted for phase-in of Tier 3 standards" to end of caption for each table

Figure 2-29 - Suggest adding to the caption "Base Rate is prior to adjustment for phase-in of Tier 3 standards". The MOVES2014 PM emission rates and the new PM emission rates for 201X for the model years 2004 - 2015 differ by more than a factor of 2. It is quite useful to compare current and past estimates as you do here, as it gives the reader some idea of the uncertainty surrounding these estimates and I think the EPA should consider adding this type of graph to every section of the report. It would be useful to explain why you think this significant change occurred and consider if a similar uncertainty surrounds this new modeling effort.

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

Section 2.3.2

Second paragraph - MSAT-2 (Mobile Source Air Toxics) rules apply to fuels, so vehicles cannot be MSAT-2 compliant.

Table 2-11 - third study is a tunnel study - this type of study cannot be used to tease out small differences in gasoline PM_{2.5} tailpipe emissions between winter and summer. The authors did not attempt this for good reason. There can be significant differences in the PM on the roadway between summer and winter unrelated to gasoline tailpipe emissions such as the application of salt. Gasoline tailpipe PM emissions are only a small part of the total PM measured. EPA's Chemical Mass Balance (CMB) model used in this analysis does not differentiate between tire wear emissions and gasoline vehicle tailpipe emissions because they have a similar chemical profile. For all these reasons this study is not applicable to drawing a conclusion one way or the other on the effect of temperature on small changes in running PM_{2.5} emissions from gasoline vehicles and should be removed.

**WA 0-14: Peer Review of
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Peer Review Charge Addendum

Specific Charge Question

1. As discussed in the *Speciation* and *Air Toxic Emissions* reports, EPA developed a TOG speciation profile from ACES Phase II, using the data collected on the 16-hour transient cycle, and an average of the data collected from the three tested engines. The TOG speciation profile from ACES Phase II has a 0 methane, as opposed to 58% methane in the ACES Phase I profile used to represent 2007-2009 heavy-duty trucks. Other anomalies were also noted in the speciation profile. For example, benzene was not detected (ND) (from which we then assumed benzene=0), while ethanol comprises over 3% of the TOG emissions, due to one of the 3 engines in ACES Phase II reporting over 8% ethanol in the VOC emissions.

We are proposing to use the ACES Phase II profile as the source of toxics and for developing a speciation profile for developing chemical mechanism species for air quality modeling. Do you have any recommendations regarding the use of the ACES Phase II TOG Profile in MOVES? Do you think it should be corrected/updated based on engineering judgment or test data collected from other 2010+ diesel engines? How should we consider correcting the profile data to accurately represent 2010+ diesel exhaust?

For your reference, we have attached the speciation profile (speciate_95355_2011_diesel_TOG.xlsx) obtained from the EPA SPECIATE database (<https://cfpub.epa.gov/speciate/>), an OTAQ spreadsheet (HD 2010+ Toxics Speciation Factors_rev.xlsx) used to derive toxic fractions for MOVES from the ACES Phase II data, and detailed data reported from the ACES Phase II study, obtained from the CRC webpage (Detailed Chemistry-FTP-Site.xlsx).

Additional attachments:

- *speciate_95355_2011_diesel_TOG.xlsx*
- *HD 2010+ Toxics Speciation Factors_rev.xlsx*
- *Detailed Chemistry-FTP-Site.xlsx*

Reviewer Response to Peer Review Charge Addendum

This issue is to some degree addressed above, where I expressed skepticism on the number of significant digits with which the data from this study was presented.

Before making any specific recommendations I would propose the following analysis: There were several compounds which were not detected in 2010+ MY emissions which were detected in 2007 MY emissions and perhaps vice versa; calculate changes in emissions rates between the two sets of data

only after replacing the non-detects with one half of the method detection rate. Then consider each of the compounds within its group of similar compounds - say all alkanes, or all PAHs - are there consistent trends in the emission rate changes for all of the compounds within each groups of similar compounds? Consistent trends suggest that individual emissions data is reasonably accurate, while big variability suggests that the data for individual compounds is not accurate. Consider also how close individual emissions results are to the method detection limit. If the measurements are very close to the detection limit you might only trust the analytical value to be accurate within a factor of 2 to 10. If all this suggests that the data is reasonably accurate then trust the results and use the data as is.

If these results suggest that the results for individual compounds are not accurate enough than one possibility which EPA might wish to consider is to calculate the percentage reduction in total organics between 2007 MY and 2010+ MY data and then use that value as a multiplier for individual organics to estimate the amount of toxics emitted in 2010+ MY. They could refine this further by using a single value for groups of compounds (alkanes, PAHs etc.). There are values for this in the ACES Phase II CRC report, Table ES-2.

I am not aware of any other comparable studies of 2010+ MY diesel emissions, but a literature search should be conducted to see if any other comparable data is available that can help refine this estimate.