Task 4: Final Report: Peer Review of

Evaporative Emissions Report

in Support of MOVES2013

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Prepared for

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1. Introduction

The MOtor Vehicle Emission Simulator (MOVES) was developed as part of OTAQ's comprehensive approach to address the impacts of light- and heavy-duty vehicles on air quality and public health. MOVES is OTAQ's current emission modeling system, capable of estimating emissions for a broad range of pollutants from on-road cars, trucks & motorcycles at multiple analysis scales, including the impact on air quality of light duty vehicle (LDV) fleet evaporative emissions. Future versions of MOVES will add various enhancements to this model, including the ability to simulate emissions from non-highway mobile sources.

As part of the development of the next release version, MOVES2013, EPA is preparing five reports/analyses documenting the results of various inquiries into the nature of fuels, vehicle exhaust and evaporative emissions on air quality. These reports detail how EPA intends to update MOVES' ability to model policy outcomes from proposed changes in the understanding of the US vehicle fleet and to help mitigate any adverse air quality impacts associated with future motor vehicle fuels.

This document reports the findings of an external peer review of one report:

- The MOVES2013 Evaporative Emissions Report.

This peer review was conducted from July 2013 to September 2013 according to *EPA's Peer Review Handbook, Third Edition*. These guidelines specify that all highly significant scientific and technical work products shall undergo independent peer review per specific agency protocols to assure the use of the highest quality science in its predictive assessments and assure stakeholders that each analysis/study has been conducted in a rigorous, appropriate, and defensible way.

This document contains the conclusions of each peer reviewer on each document included in the review, by charge question. Supporting documentation collected from the reviewers, including their curriculum vitae (CV) and conflict of interest (COI) statements, is also provided in Appendix A and Appendix B. The Task 3: Peer Review Process Report describes the process to select reviewers and administer the peer review. At the conclusion of the review, ICF collected all peer review comments and cover letters in order to provide them to EPA, unedited. The following materials are included in this Task 4 Technical Report.

1. Reviewer Responses to Charge Questions (Section 4)
2. Reviewer Supporting Documentation (Appendix A and Appendix B):
    a. Reviewer Delivery Email (i.e., Cover Letter)
    b. Reviewer CV
    c. Reviewer COI Statement

2. Peer Review Process

Full documentation of the process to select reviewers and administer the peer review is included in the Task 3: Peer Review Process Report. This section summarizes the process that resulted in the selection of Chris Kite and Dr. Robert Sawyer as reviewers of the Evaporative Emissions Report.

2.1. Reviewer Selection

ICF identified a pool of independent subject matter experts to conduct this review. Initial contact to each reviewer confirmed the potential reviewer's expertise in the field, their ability to perform the work during the period of performance, any association with whom they have worked that might preclude them from being an independent and objective reviewer, their hourly billing rate, and to confirm their contact information. A curriculum vitae or resume for each peer review candidate that expressed interest and availability. This list was submitted to EPA for approval and revisions, as necessary. Multiple iterations were made to the list of selected reviewers before a set of available, conflict free reviewers for the Evaporative Report were agreed upon. The final pool of potential candidates was contacted via e-mail and phone. Additionally, a final peer review selection memo was delivered to EPA.

2.2. Administration and Completion of the Peer Reviews

Following acceptance of reviewers by EPA and by reviewers to participate, the review was administered according to the below process:

- A charge for each report was drafted with instructions to provide clear and detailed comments that distinguish between recommendations for improvements and, if appropriate, what conclusions could be drawn from the report and/or subsequent model predictions
- Electronic distribution of the review material, including the report charges,
- For each report, a teleconference was arranged between the selected peer reviewers, the EPA WAM, EPA-identified relevant project-related staff, and ICF staff. The purpose of these calls was to clarify any questions the reviewers had regarding the review material. EPA's purpose on the call was to provide technical and/or background support on the particular report or analysis under review, as needed,
- Any technical reviewer questions were facilitated through ICF to EPA, and
- A deadline for submission of materials.

Both selected reviewers for the Evaporative Report met the submission deadline, even though the review period was compressed. Their full set of review comments, along with their cover letters, CVs, and Conflict of Interest statements, were gathered and provided to EPA unedited.

Additionally, a technical report documenting the peer review process for each report was assembled to conclude each review. Finally, all contracting and payment issues with each reviewer were managed by ICF to ensure prompt payment of each reviewer for their services.

2.3. Difficulties Encountered

No notable difficulties were encountered in review of the Evaporative Report, although finding available reviewers without perceived conflicts of interest delayed initiation of the review and compressed the review period. It is possible that having a longer period for the selection process would have given the experts more time to think about if they want to participate, while a longer period between the selection process and the kick off call to do basic preparations for selection (e.g. Mr. Kite did not have a CV ready initially) could have lessened the burden on the reviewers.

2.4. Supporting Documentation

Supporting documentation collected from Dr. Sawyer and Mr. Kite is captured in Appendices A and B. This includes the reviewers' cover letters, conflict of interest statements, and CVs.

3. Charge Questions and Scope of the Peer Review

The peer reviewers were asked to review the MOVES 2013 Evaporative Emissions Report. Responses were requested to five general questions and one catch-all question. One report-specific charge questions was also included. These are repeated below.

3.1. General Charge Questions

The general charge questions were as follows:

1. Does the presentation give a description of selected data sources sufficient to allow the reader to form a general view of the quantity, quality and representativeness of data used in the development of emission rates? Are you able to recommend alternate data sources might better allow the model to estimate national or regional default values?
2. Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA to develop the model inputs? Are examples selected for tables and figures well chosen and designed to assist the reader in understanding approaches and methods?
3. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs? In making recommendations please distinguish between cases involving reasonable disagreement in adoption of methods as opposed to cases where you conclude that current methods involve specific technical errors.
4. In areas where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions made are appropriate and reasonable? If not, and you are so able, please suggest alternative sets of assumptions that might lead to more reasonable or accurate model inputs while allowing a reasonable margin of environmental protection.
5. Are the resulting model inputs appropriate, and to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in exhaust emissions formation and control? Are the resulting model inputs empirically consistent with the body of data and literature that has come to your attention?

The catch-all charge question was as follows:

1. Please provide any additional thoughts or review of the material you feel important to note that is not captured by the preceding questions.

3.2. Report-Specific Charge Question

The charge question specific to the review of the Evaporative Emissions Report was as follows.

1. Compared to current methods, is the proposed methodology for estimating evaporative emissions a significant improvement? Would a simpler application of the ideas contained in this method be adequate? Are there other existing models for evaporative emissions that might be possible candidates for inclusion in MOVES?

3.3. Conclusion of the Peer Review

The compiled set of unedited reviewer comments for each charge question is provided in Section 4. Each reviewer's delivery emails (i.e., cover letters), CVs, and COI statements were also gathered and are provided in Appendix A and Appendix B for each reviewer in PDF format or in the referenced attachments. This Task 4 Technical Report concludes the review.

4. Reviewers' Responses to Charge Questions

4.1. Evaporative Emissions Report

This section provides a verbatim list of peer reviewer comments submitted in response to the charge questions for the Evaporative Emissions Report.

4.1.1. Adequacy of Selected Data Sources

Does the presentation give a description of selected data sources sufficient to allow the reader to form a general view of the quantity, quality and representativeness of data used in the development of emission rates? Are you able to recommend alternate data sources might better allow the model to estimate national or regional default values?

4.1.1.1. Chris Kite

No response.

4.1.1.2. Dr. Robert Sawyer

New evaporative emissions data come largely from the extensive Coordinating Research Council studies reported in 2006-2010. These data, particularly quantification of permeation data, are a major improvement over the sparse data previously available. The report documents these data thoroughly and clearly.

4.1.2. Clarity of Analytical Methods and Procedures

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA to develop the model inputs? Are examples selected for tables and figures well chosen and designed to assist the reader in understanding approaches and methods?

4.1.2.1. Chris Kite

No response.

4.1.2.2. Dr. Robert Sawyer

Descriptions of methods and procedures are particularly good. Explanation of the operation of evaporative control systems and the nature and mechanism of emissions is excellent. The writing in this report is concise, direct, and clear. The use of graphics to show relationships, and agreement with experimental data as available are very well done.

4.1.3. Appropriateness of Technical Approach

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs? In making recommendations please distinguish between cases involving reasonable disagreement in adoption of methods as opposed to cases where you conclude that current methods involve specific technical errors.

4.1.3.1. Chris Kite

No response.

4.1.3.2. Dr. Robert Sawyer

The estimation of fuel system evaporative emissions depends strongly upon the "fuel tank temperature". The use of this term is a bit ambiguous. I believe that it refers the temperature of the fuel in the fuel tank. This should be made clear.

For hot and cold soaks, modeling of the change in fuel temperature based on the fuel temperature, air temperature, and a transfer coefficient (equation 1) is probably adequate for the purposes of the model, however it fails to capture difference in fuel tank design. "k" comes from EPA compliance test data. Reporting of the variability in "k" would give some sense of the adequacy of the model.

Similar questions arise in the use of equation 3 to model fuel tank temperature during running operation. Vehicle to vehicle variation is likely to be even larger and should be quantified. Note: MOVES projects fleet average emissions, which will change as vehicle designs change. Use of a fleet-average constant will not capture possible changes as older model years disappear from the fleet. A model-year or binned model year constant would be an improvement.

4.1.4. Appropriateness of Assumptions

In areas where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions made are appropriate and reasonable? If not, and you are so able, please suggest alternative sets of assumptions that might lead to more reasonable or accurate model inputs while allowing a reasonable margin of environmental protection.

4.1.4.1. Chris Kite

No response.

4.1.4.2. Dr. Robert Sawyer

Inadequate or missing data is always a problem. The assumptions used to deal with inadequate data are clearly stated. The use of current and projected emissions standards to project future vehicle fleet emissions has a history of underestimating emissions.

The use of light-duty vehicle evaporative emissions composition data for non-existent heavy-duty gasoline vehicle data is reasonable. There is no reason to expect that differences in vehicle designs between these two categories of vehicles would affect evaporative emissions significantly.

Linear interpolation and extrapolation for the estimation of altitude effects is reasonable.

The assumption that fuel tank size will remain constant at the current level of 19 gallons over the 2009-2030 period, page 21, is incorrect. With an improvement of fuel economy by nearly a factor of two over this period, than size will decrease by roughly the same factor, as occurred in the 1970s.

4.1.5. Consistency with Existing Body of Data and Literature

Are the resulting model inputs appropriate, and to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in exhaust emissions formation and control? Are the resulting model inputs empirically consistent with the body of data and literature that has come to your attention?

4.1.5.1. Chris Kite

No response.

4.1.5.2. Dr. Robert Sawyer

Model inputs are consistent with the goal of MOVES to be more data driven. However, major gaps remain in the available data. Particularly sparse are data on liquid running losses, Table 17. The methodology of subtracting modeled estimated vapor emissions from total measured vapor emissions from vehicles excluded from inspection and maintenance testing is suspect.

Liquid spillage during refueling comes from AP-42 and data apparently dating from the 1970s. This is a major shortcoming of the MOVES2014 model and deserves attention in a future revision or updating. The effective regulation of other emissions increases the importance of unregulated or weakly regulated emissions.

Additional information on the Wade-Reddy equation for vapor generation (equation 6) is needed as this relation is used extensively in the modeling. First, no reference is provided. Second, having a figure in which the data to which the equation was fitted with the coefficients of Table 7 would strengthen the rationale for the use of this empirical relation. I believe that this relation comes from work first published in the 1970s (perhaps: Wade et. al., “Mathematical Expressions Relating Evaporative

Emissions from Motor Vehicles without Evaporative Loss-Control Devices to Gasoline Volatility," SAE Paper 720700, 1972?) and has been cited extensively over the years in EPA publications on evaporative emissions. I have not reviewed the source paper. It is a reasonable mathematical curve-fit relation, but its original justification probably was with data of the 1970s. The data are modern and appropriate, but how well the model fits the data should be shown.

4.1.6. Improvements in Proposed Methodology

Compared to current methods, is the proposed methodology for estimating evaporative emissions a significant improvement? Would a simpler application of the ideas contained in this method be adequate? Are there other existing models for evaporative emissions that might be possible candidates for inclusion in MOVES?

4.1.6.1. Chris Kite

No response.

4.1.6.2. Dr. Robert Sawyer

Improvements in the treatment of evaporative emissions are substantial. The data base, the modeling of emissions, and their integration with fleet composition and activity all are significant improvements over the current MOVES model. Treatment of the addition of ethanol is straight forward, carefully done and presented, and an important addition.

4.1.7. General/Catch-All Reviewer Comments

Please provide any additional thoughts or review of the material you feel important to note that is not captured by the preceding questions.

4.1.7.1. Chris Kite

- Overall, the technical report is very informative and well written. While reviewing the report for areas in which I have some background, I came across many sections where I was less informed, so it was a very positive experience to learn more about evaporative emission processes and how the MOVES model treats them.
- While reviewing, I noticed some minor grammatical issues that I noted with recommendations for correction, rewording, etc. These may be of help in preparing the final version of the report, but since such suggestions are rather minor and not essential for a peer review, they are highlighted with notes in the attached draft but not mentioned here.
- The report included a few references that may need to be corrected once the final version is prepared so that someone reading it a few years from now will not be confused:

  - The draft mentions a MOVES2014 version of the model. Will the evaporative emission impacts referenced in the report be included in the upcoming MOVES2013 version? If so, then just change the reference to MOVES2013. If not, is a MOVES2014 version of the model already under development that will include these impacts? Or, if there will not be a MOVES2014 version of the model, just change this to MOVES2015, MOVES2016, etc. as needed.
  - The report draft was probably written when 2016 was being considered as a model year start for Tier 3 standards with a phase-in from 2016-2022. Based on the Tier 3 proposal from earlier this year, this should be changed to a 2017 model year start with a phase in from 2017-2025. In the event that Tier 3 implementation is delayed beyond 2017, then the report draft should be modified accordingly.

- The report draft mentions the Stage 2 program, but we recommend referring to it as Stage II since the latter is typically how the rule is typically referenced in the Clean Air Act and by EPA.

  In footnote #2 on page 9, a 15-minute time increment is referenced for hot and cold soak emission calculations. This time increment seems very reasonable, but I was left wondering how MOVES handles temperature figures for each 15-minute increment. Are they just linearly interpolated from the hourly MOVES model inputs? The manner in which I prepare MOVES temperature inputs are averages for the entire hour, so if data were collected at several meteorological stations from 7-8 AM, then I would average all of these and associate the input with an hourID of 8 in the zonemonthhour table. Pretend I had a 7-8 AM figure of 70 F and an 8-9 AM figure of 74 F. Would the evaporative calculations put the 70 F and 74 F estimates right at the top of the hours, which would be 7 AM and 8 AM, respectively? Or, would these be put at the mid-point of the hours, which would be 7:30 AM and 8:30 AM, respectively? Assuming the latter, then would the evaporative calculations be based on a linear interpolation of 70 F at 7:30 AM, 71 F at 7:45 AM, 72 F at 8:00 AM, 73 F at 8:15 AM, and 74 F at 8:30 AM? If this is documented elsewhere, then just reference that literature instead of including a full and rather tedious explanation in this report.

- The approach described on page 16 to vary evaporative effects by altitude (instead of “low” versus “high” categories) is excellent. With the MOVES county database table now include a numeric elevation field to perform this calculation?

- The summary is very good about how MOVES handles diurnal emissions from vehicles parked for several days without initiating trips. Figure 13 on page 27 is particularly good at communicating the necessary points. I looked at the samplevehicleday and samplevehicletrip tables in the MOVES2010b database, and couldn’t figure out how to obtain the fractions of vehicles cold soaking for several consecutive days. The current tables look like they were designed for a sample vehicle on a single day. Perhaps these tables will be expanded for a future version of MOVES? If so, then I recommend including an extract of the expanded table(s) in Appendix B. Also, the samplevehiclesoakingday table referenced on page 27 is currently empty within the MOVES2010b database. Perhaps this contains the needed information to view multiple-day cold soak profiles? If so, then I recommend including an Appendix B extract of this table as well. Maybe only have these example extracts focus on the gasoline passenger car source use type to keep them small.

Whatever approach is taken should make it very clear to the reader about how to connect all the tables together. I do not expect that many MOVES users will have their own multi-day soaking data for populating these tables (and will instead rely on defaults), but the necessary methodology should be outlined clearly in the event that users do want to provide their own information.

- In Section 3.3.4 on page 36, it says that MOBILE6 was run to obtain the effects of temperature and gasoline RVP on running loss emissions. I understand that this may have been necessary in lieu of having superior data, but are there no newer data sets available that can be used for this purpose? To understand how MOBILE6 handles this, I came across a report entitled Estimating Running Loss Evaporative Emissions in MOBILE6, M6.EVP.008,EPA420-R-01-023, April 2001, which is on the MOBILE6 Technical Documentation site (http://www.epa.gov/otaq/models/mobile6/r01023.pdf). Under Section 5, Conclusions, on page 7, it says: "EPA proposes, for MOBILE6, to use the MOBILE5 model to estimate the running loss emissions from that portion of the fleet that does not contain vehicles that are gross liquid leakers." Is there justification available to indicate that the changes in vehicle technology over the last 20-25 years are not sensitive to the response of temperature and fuel RVP to running loss emission rates? If not, that should be emphasized in the report so that readers are aware that newer data of this sort be assigned appropriate priority for future research. MOBILE5 was released before the introduction of Tier 1 and LEV-I vehicles into the fleet, so it is likely that the raw data upon which the MOBILE5 running loss impacts were developed dates back to vehicles tested from 1980-1990. Assuming that some updates were done for estimating running loss emissions with MOBILE6, the test data then would have perhaps included Tier 1 and LEV-I vehicles that were available from 1990-2000. Since the current light-duty fleet is dominated by 2004-and-newer Tier 2 activity, it would be ideal for MOVES to not rely on data of such vintage, particularly for a model that will be used to estimate future fleet emissions dominated by both Tier 2 and Tier 3 vehicles.
- In Section 3.6 on page 42, it says: "Refueling emissions are estimated from the total volume of fuel dispensed (gallons). This volume is estimated from the average daily distance travelled (VMT) and estimated fuel consumption." Is this how MOVES performs the calculations "under the hood" for refueling? If MOVES2010b is run to obtain refueling emission rates, the three types of output are grams/mile, grams/start, and grams/hour for the respective activity types of miles traveled, number of starts, and number of extended idling hours for diesel-fuel combination long-haul trucks. These are the same emission process/rate combinations when estimating carbon dioxide (CO2) and energy consumption. I have not been able to obtain gallons pumped/consumed directly from MOVES output, and have instead relied on post-processing CO2 and/or energy consumption for these purposes. Will future versions of MOVES estimate gallons pumped/consumed directly or output refueling emission rates in units of grams/gallon? If not, then the report language referenced above about how MOVES calculates refueling emissions may need to be revised.
- Could this report or some other MOVES documentation include options/recommendations about how specific evaporative emission processes should be matched to profiles from EPA's SPECIATE database? Refer to slides 8 and 9 of the attached file entitled "mvs-custom-scc-and-speciation-tceq.pdf". Based on the most recent information that we could obtain, this is how we are matching

up evaporative emission processes to SPECIATE profiles. For example, evaporative permeation from running vehicles is matched to profile descriptions that begin with "dynamic permeation". Off-network evaporative permeation from parked vehicles is matched to profile descriptions that begin with "static permeation". Vapor/venting processes get matched to "headspace vapor", while leaking/spillage profiles get matched to liquid fuel composition. This was the best matching I could come up with, but it took a lot of staff time to develop, and it will likely be very helpful for new MOVES users to have some guidance/direction about where to start in case they have similar questions. If you feel that these tables reflect a good starting point, feel free to use them. Prior to 2008, ethanol had not fully penetrated the fuel supply in Texas, so we are relying on gasoline profiles that have both 0% and 10% ethanol. If you feel that we could take an improved approach with this matching, please let us know.

- Overall, excellent report and thanks for the opportunity to review.

4.1.7.2. Dr. Robert Sawyer

- The treatment of evaporative emissions in MOVES2014 is a significant improvement over the previous treatment. The incorporation of extensive new data, reorganization of the computation of total evaporative emissions, and integrating evaporative emissions with data on fleet composition and operating modes all contribute to this improvement. Non-tailpipe emission sources not treated include window washer fluid, paint, and plastics and rubber off-gassing. Some of these sources may not be significant, but for completeness they deserve recognition.
- Increasing skewness in evaporative emissions, as in tailpipe emissions, points to the importance of getting the high emitter effect correct. Both emissions rates and activity data require refinement. Model-year emissions in MOVES vary by a factor of 50 or more.
- A glossary would be useful.

Appendix A. Chris Kite's Supporting Documentation

A.1. Reviewer's Delivery Email (i.e., Cover Letter)

See file: *Chris Kite Peer Review.msg.pdf*

A.2. Reviewer's CV

See file: *Kite_Resume.pdf*

A.3. Reviewer's COI Statement

See file: *COI_Disclosure_Kite-Signed_Redacted.pdf*

Appendix B. Dr. Robert Sawyer's Supporting Documentation

B.1. Reviewer's Delivery Email (i.e., Cover Letter)

See file: *Robert Sawyer Peer Review.msg.pdf*

B.2. Reviewer's CV

See file: *Resume_Sawyer.pdf*

B.3. Reviewer's COI Statement

See file: *COI_Disclosure_Sawyer_Redacted.pdf*

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