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Monday, December 14, 1998

Ms. Penny Carey
U. S. Environmental Protection Agency
Assessment and Modeling Division/SAG
2000 Traverswood Drive
Ann Arbor, MI 48105

Dear Ms. Carey:

I have enclosed the peer review of the four EPA reports shown below in fulfillment of your order number 9A-0152-NATX, dated November 10, 1998.

> Report number M6.STE.002 entitled "The Determination of Hot Running Emissions from FTP Bag Emissions," September 1997.
>
> Report number M6.STE.003 entitled "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981 - 1993 Model Year Light Duty Vehicles," October 1998.
>
> Report number M6.EXH.001 entitled "Determination of Running Emissions as a Function of Mileage for 1981 - 1993 Model Year Light-Duty Cars and Trucks," October 1998.
>
> Report number M6.EXH.002 entitled "Analysis of Emissions Deterioration Using Ohio and Wisconsin IM240 Data," October, 1998.

I have conducted the review in accordance with the instructions in the November 3, 1998 cover letter to the report package from Phil Lorang. Following those instructions, I am providing my report as an enclosure to this letter and I have provided a copy of the review in a Word Perfect 6.0/6.1 format on the enclosed disk. The information in the next two paragraphs responds to the information requested in Phil Lorang's cover letter.

In preparing this review I have been acting as an independent consultant. My official contact address for this project is shown at the top of this letter. My principal employment is as Dean of the College of Engineering and Computer Science at

California State University, Northridge. None of the work for this review was done as part of the duties for that job and does not represent any opinions on the part of CSU, Northridge. I have no real nor perceived conflicts of interest in the conduct of this review. I estimate that I have spent 50 hours in reviewing the reports and preparing the documents submitted here.

My qualifications for this review are summarized in this paragraph. I have provided a copy of my resume showing additional details of my qualifications for this review. Starting with my graduate research, most of my professional work has involved the study of emissions from a variety of combustion sources, especially motor vehicles. This includes experimental studies on engines, modeling studies on various combustion sources, and experimental and modeling studies on catalysts. I served for five years as the automotive engineering member of the California Air Resources Board and was the original representative from the South Coast Air Quality Management District to the California I/M Review Committee. From 1992 to 1997 I was a partner at Sierra Research where I worked on many studies related to motor vehicle and stationary source emissions. This included studies for government agencies, including the U. S. Environmental Protection Agency, and for private industry. A significant part of my work at Sierra was on the development of a major revision to the California Air Resources Board mobile source emission inventory model. This revision, which had the internal working name EMFACX, is scheduled for release early next year. My work on that model included both emissions analysis and coding. I was responsible for analyses similar to those in the reports under review for this project.

Please feel free to contact me if you have any questions on the information in this letter or in the enclosed report. I intended the enclosed report to be a final draft. However, if EPA staff find any incorrect or unclear portions of the report I would be glad to prepare a revised copy with the appropriate corrections or clarifications.

Sincerely,

Larry Caretto

enclosures: resume
copy of invoice
review document
disk with Word Perfect 6.0/6.1 files for review document

REPORT REVIEW

DEVELOPMENT OF START AND RUNNING EXHAUST EMISSIONS EQUATIONS IN MOBILE6

Prepared for U. S. Environmental Protection Agency
Under Order Number 9A-0152-NATX

December 14, 1998

L. S. CARETTO
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INTRODUCTION

The U. S. Environmental Protection Agency (EPA) requested an independent peer review of the four reports listed below. These four reports were one part of the work being done to provide an updated version of EPA's mobile source inventory model, MOBILE6.

> Report number M6.STE.002 entitled "The Determination of Hot Running Emissions from FTP Bag Emissions," September 1997.
>
> Report number M6.STE.003 entitled "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981 - 1993 Model Year Light Duty Vehicles," October 1998.
>
> Report number M6.EXH.001 entitled "Determination of Running Emissions as a Function of Mileage for 1981 - 1993 Model Year Light-Duty Cars and Trucks," October 1998.
>
> Report number M6.EXH.002 entitled "Analysis of Emissions Deterioration Using Ohio and Wisconsin IM240 Data," October 1998.

EPA provided copies of the reports, an overview of the linkages between the reports, overall directions for this review, a disk containing two Excel spreadsheets showing how emissions were computed for cars and trucks, and a list of issues to be addressed. Besides these materials, EPA staff provided additional data and clarifying comments during the progress of the review.

EPA asked that the review address the following areas:

1. report clarity,
2. general review of overall methodology,
3. appropriateness of the data sets,
4. the data analyses conducted, including the statistical approaches used and models selected.
5. appropriateness of the conclusions, and
6. recommendations for any alternate data sets or analyses.

This review begins with a section on overall comments on the four reports followed by a section which addresses the issues on the list provided by EPA. Following that section, individual sections provide additional discussion for each report. The final section provides overall conclusions and discusses the appropriate priorities, as requested by EPA, for the suggested alternative analyses made throughout this review.

OVERVIEW OF THE FOUR REPORTS

Background

The MOBILE program computes the emissions from a variety of vehicles including light-duty and heavy-duty vehicles with both gasoline and diesel engines. The four reports reviewed here are concerned with hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) emissions from light-duty vehicles. These include passenger cars and trucks with a gross vehicle weight rating (GVWR) between zero and 8,500 pounds.*

Emissions from these vehicles depend, in part, on their model year, their mileage driven, their emissions-control and fuel-metering systems, and the kind of inspection and maintenance (I/M) program to which they are subject. The actual in use vehicle emissions depend on the driving pattern of the vehicles. The four reports described here are aimed at describing the emissions from light-duty vehicles manufactured during the 1981-1993 model years under operating conditions encountered during the certification test known as the Federal Test Procedure (FTP). The effects of I/M and of actual driving conditions are not addressed in these reports.

A major thrust of the MOBILE6 revisions is the development of a distinction between running emissions and start emissions. The four reports reviewed here discuss this distinction and the methods used to determine both kinds of emissions. Equations are derived which calculate both types of emissions as a function of vehicle mileage for specific technology groups. (A technology group is a consistent set of model years, fuel-metering systems, and emission-control systems; seven technology groups for passenger cars and five technology groups for light-duty trucks are used for the 1981-1993 model years considered in these reports.)

General comments on the set of four reports

These general comments address issues that are present in all reports. They are organized by the six comment areas requested by EPA.

*This review uses the term light-duty vehicles to refer to light-duty cars and trucks. EPA conventionally reserves the term light-duty vehicles for passenger cars.

Report clarity

EPA staff provided charts and tables showing the relationship among the four reports when they were submitted for review. This is an indication that EPA staffs recognize that they have prepared four separate reports that need to be linked. However, there currently is no overview report providing this linkage. These reports are actually progress reports on a large-scale project – the revision of the MOBILE model. EPA staff should consider the preparation of an overall report to accompany the release of the final version of MOBILE6 that would give an overview of the process used to develop the various components of the model. Such a report would show the linkages among the various tasks that are not clear from a reading of the current individual reports.

Overall methodology

The separation of FTP emissions into start emissions and running emissions is a good approach to the modeling of emissions from actual vehicle use. This approach is a positive step to improving the ability of the model to capture actual in-use emissions from motor vehicle operation.

Appropriateness of the data sets and recommendations for alternative data sets

The data sets used in these analyses appeared to be the most useful ones for the development of emissions for the 1981-1993 light-duty vehicles. No additional data sets are recommended for the emissions analysis.

Data analyses, including statistical approaches and models

The main tool used in these reports is regression analysis. The authors have been careful to use transformations that would improve the agreement of the transformed data with the basic assumptions of regression analysis. The authors refer to several alternative analyses that, in the authors' judgement, did not provide improved agreement. The resulting models are relatively simple. This is appropriate for fleet emissions data that have a large scatter.

The presentation of the results from the regression analyses used in these reports is uneven. In some cases detailed regression statistics are presented; in some cases only a brief summary is given. Having a complete set of regression statistics for all the equations used would be helpful. The confidence limits (or confidence intervals) for the emission values predicted by the regression equations would be an informative statistic to report. This interval depends on the values of the independent variables. However, it is easily computed for the case where the value of each independent variable has its mean value in the data set used for the regression. For large sample sizes, the confidence interval is very nearly constant for the entire range of the independent variables. This is shown by the confidence limits plotted in Figures 1 and 2 in the M6.EXH.001 report.

Two such confidence limits are possible: (1) the confidence limits for the future prediction of a single value and (2) the confidence limits for the mean value of the dependent variable for a given set of independent variables. The latter is probably the more important one for the analyses presented here since the regression analyses are intended to predict mean emissions from a group of vehicles in the fleet.

If not presented in the report, the confidence limits can be simply computed by an interested reader if the value for the standard error, $s_{y|x}$, and the sample size for the regression data are reported.

Throughout the reports there is some discussion of other analyses used by EPA and rejected. It is not always clear why the alternative analysis was selected. In some of these cases, a simple statement is made that the analysis finally used provided better statistical results. Such a statement is appropriate and provides adequate explanation. In other cases, such as the decision to use mileage accumulation data in place of odometer readings, the explanation is less clear and no data are provided to support this decision. In general, it would be better to report the quantitative data used to justify conclusions made regarding alternative analyses.

Appropriateness of Conclusions

There is no explicit conclusion section in three of the reports. Report M6.EXH.002 has a section entitled “Results and Conclusions” which concludes that the approach used for the Dayton IM240 data was the best possible approach to the computation of a high-emitter correction factor. All of the reports have an implied conclusion that the data analyses were effectively done to provide an appropriate estimate of 1981-1993 light-duty vehicle exhaust emissions for MOBILE6.

The explicit or implicit conclusions and the equations proposed for use in MOBILE6 rest on statistical analyses. However, there is very little information about the expected uncertainty in such results. An estimate of the probable error in the final equations should be provided. Additional comments on the appropriateness of the conclusions are presented in the following sections.

COMMENTS ON ISSUES REQUESTED BY EPA

Background

EPA provided a list of nine issues representing major choices and assumptions in the analysis of start and running emissions. These issues, and the reports that deal with them are listed in the headers below, followed by the comments on these issues.

Model year groupings and segregation of fuel system types (M6.STE.003 and M6.EXH.001)

In these analyses EPA divided the 1981-1993 light-duty vehicles into seven passenger car categories and five light-duty truck categories. These are listed below:

1981-1982 Carbureted Passenger Cars
1983-1985 Carbureted Passenger Cars
1986-1993 Carbureted Passenger Cars
1981-1982 Fuel-injection Passenger Cars
1983-1987 Fuel-injection Passenger Cars
1988-1993 Port Fuel-injection Passenger Cars
1988-1993 Throttle-body Fuel-injection Passenger Cars

1981-1983 Carbureted Light-duty Trucks
1984-1993 Carbureted Light-duty Trucks
1981-1987 Fuel-injection Light-duty Trucks
1988-1993 Port Fuel-injection Light-duty Trucks
1988-1993 Throttle-body Fuel-injection Light-duty Trucks

According to the reports these groupings were selected on the basis of “changes in emission standards or the development/refinement of new fuel metering or catalyst technologies.”

The basis for the choice of technology groups is sound. The final decision of the number of groups to select depends not only on the similarity of the vehicles but also on the data availability. From the tables showing the number of data vehicles with FTP results (e.g., Table 1 in M6.STE.003), there is an appropriate amount of data for each group used in the analysis.

Although the choices appear reasonable, there are no analyses presented to justify the choices. For example, would it be better to distinguish between port and throttle-body injection vehicles earlier than the 1998 model year? A less important question, due to the small number of carbureted vehicles, would be a possible distinction between open-loop and closed-loop carbureted vehicles. There may be good reasons for the choices made, but there are no data to justify the choices in the report. It is possible to use an analysis of covariance technique to determine whether alternative choices of groups would provide better similarity within each group.

Any data analysis that was done to consider different possible groupings should be reported, at least in a summary. However, it should not be necessary to do any additional work to analyze alternative groupings of 1981-1993 light-duty vehicles.

Separation of FTP measurements into start and running emissions based on results from 76 cars (M6.STE.002)

The separation of exhaust emissions into running emissions and start emissions is a good choice. Furthermore, the definition of the hot running 505 emissions and its use to compute start and running emissions appears to be the most logical choice. The definitions of running emissions as the sum of bag two plus the hot running 505 is consistent with the original definition of the LA4 cycle. Similarly, the definition of start emissions as bag one minus the hot running 505 for a twelve-hour soak (and bag three minus hot running 505 for a ten minute soak) should correctly represent the start emissions. Older versions of the California Air Resources Board (CARB) emissions model, EMFAC, up to and including EMFAC7F, used an algorithm involving the emissions from the first and third bags to deduce start emissions. In those models running emissions were associated only with bag two. The definition adopted for MOBILE6 is fundamentally a better definition than the simpler approach used in EMFAC7F.[*]

The real issue here is whether or not there are sufficient data to use the definition of start and running emissions adopted by EPA. Because there is not an extensive data base on the hot running 505 emissions, EPA has relied on a data set of 76 vehicles (77 vehicles less one outlier) to determine an empirical relationship between FTP emissions and hot running emissions. The fleet for which these data are obtained in described in general terms as including cars and trucks “weighted predominately toward late model

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[*]A later version, EMFAC7G, splits the emissions into running and start emissions using an approach similar to the one proposed for MOBILE6. However, in that model the running emissions are still associated with bag two only and start emissions are not linked to the 505-second cycle for bags one and three.

year vehicles and newer technology." (The average model year in this data set was 1991.) The regression equations derived from this set of vehicles would have better applicability for the later model years and technologies as opposed to the 1981-1993 model year range covered by other reports reviewed here.

The removal of vehicle 16 as an outlier appears to be a reasonable decision. It was prompted not only by the data themselves, but also by an analysis of the vehicle's emission-control system behavior. The latter showed erratic results for the different phases of the emission test. An additional vehicle (number 219) also appears to be an outlier, at least for CO and HC emissions. No mention was made of any statistical tests that could be used to detect outliers; such tests could be applied to determine if it is appropriate to drop vehicle 219 as well as vehicle 16 from this data set.[*]

The derivation of regression equations for the hot running 505 emissions is a straightforward analysis and the report presents the results from two possible approaches. The first approach uses the emissions data directly; the second uses the logarithms of the data. The report notes that the use of vehicle model year as a regression variable "added little to the predictive power of the model" and was not used in the final results. There may be some inconsistency in the rejection of model year data as insignificant, but the retention of insignificant regression parameters such as the bag-one emissions for the logarithmic CO and NOx regressions. However, this cannot be judged since the statistical parameters for the analysis with model years were not presented. This inconsistency should not have any significant effect on the final results.

Both the linear and logarithmic regressions have high values of R^2. These values indicate that the variation in the hot running 505 emissions are well explained by either model. The choice of the logarithmic model is appropriate. Both models provide valid *least-squares* results, which do not depend on any assumptions about the underlying distributions. However, the more nearly normal residuals in the transformed model provide greater validity to the significance tests.

The values for the hot running 505 cycle (with no start) would be expected to be close to the bag three data (with a ten-minute engine-off time before starting the engine). This expected physical relationship should be true in both the 76 vehicle fleet used for the development of the regression equation and in the fleets to which the regressions are applied for predictions. This expected close physical relationship, along with the high R^2 values in the regressions implies that the regression equations should be good predictors of the hot running 505 emissions.

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[*]The hot running 505 emissions data were not included in Table 1 of the M6.STE.002 report; the data were provided in an electronic format by Ed Glover of EPA.

Because of the close similarity between bag three and the hot running 505 emissions noted in the previous paragraph, the regression equations would be expected to have a very strong dependence on the bag three results. In general, however, the results show approximately equal magnitudes for the bag two and bag three regression coefficients. This may be due to a high correlation between bag two and bag three and it is not clear how much the use of additional bag data adds to the final regressions. The report discusses the use of various possible regressors, but does not discuss a simple regression (either linear or logarithmic) using only bag three as the regressor. Such a regression equation provides nearly the same value of R^2 as the regression equations presented in the report.

Running emissions versus mileage follows a piecewise linear function (M6.EXH.001)

No statistical data are presented to justify the choice of the piecewise linear functions as compared with any other possible fits. According to the report, the final choice of the equations was based on a balance between simplicity and engineering judgement. No data are reported on the statistical analysis used to reject the various alternative models tried.

Data on fleet emissions versus mileage have a large scatter. Because of this, anything but the simplest data fits cannot be justified. The analyst is typically afforded the choice of various models, all of them with low significance and low values of R^2. That presumably is the situation faced in the analysis reported here, but the authors never explicitly say so.[*] Given this typical data scatter, there is no apparent alternative to the piecewise linear approach that would give a significantly better representation of the data.

The approach in this report uses the fundamental assumption that there is zero deterioration for low mileage vehicles in the FTP data set. (The piecewise linear functions come from the analysis of the FTP data set; the correction from the analysis of the Dayton data provides a modification to the piecewise linear regression equations found from the analysis of the FTP data set.) There is no statement that this assumption was checked by testing the hypothesis that regression slope for low mileage is not significantly different from zero. Such a check would provide added support to at least one part of the piecewise linear regression equations.

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[*]EPA staff have prepared charts for various workshops on the MOBILE6 model which show this kind of scatter. It would be useful to include plots like these in a final report on the development of MOBILE6.

The discussion of the regression equations on page six of the M6.EXH.001 report states that regressions were used with all the data to obtain the lines intended to intersect the low mileage emissions line that was assumed constant. This seems to be a contradiction. If the low mileage data are assumed to have zero slope, should they be used to develop a regression equation with a slope? This is a question that has no correct answer, but it would be interesting to see whether eliminating the low mileage data from the unconstrained regression equation made any difference in the results.

FTP data sets are not considered to represent the fleet, and results based on these data sets are adjusted to match Dayton, Ohio observations (M6.EXH.001)

The differences between the FTP data sets and the Dayton data set are shown in Figures 1 and 2 in the M6.EXH.001 report. These figures would more clearly show a difference if the 95% confidence intervals were shown for both the adjusted and the unadjusted curves. Alternatively, the data might be plotted to show the differences between the FTP data and the adjusted values with a 95% confidence interval for the difference.

For the purposes of this review, a significant difference is defined to mean that the Dayton data set lies outside the 95% confidence limits for the FTP data sets. Using this definition, Figures1 and 2 in the M6.EXH.001 report show that the results from the FTP data sets and the Dayton data sets are significantly different in two-thirds of the cases.[*] In all these cases, except one, the adjusted values are higher than the FTP data. This is consistent with a recruitment-bias hypothesis: owners of vehicles with known emission problems would not submit them for an emissions study.

Even the one case in which the emissions from the Dayton data are lower than the FTP emissions – NOx emissions for 1981-1982 fuel-injected cars – is consistent with a recruitment-bias hypothesis. The HC and CO emissions for these 1981-1982 fuel-injected cars in the Dayton data are significantly higher than the FTP emissions. These higher HC and CO emissions can arise from malfunctions that lead to reduced NOx emissions. It this is true here, the lower NOx emissions and the higher HC and CO emissions for 1981-1982 fuel-injected cars are consistent with a recruitment bias.

[*]Each of the two figures contains nine cases, three mileage ranges for each of three pollutants. In twelve of the eighteen cases in the two figures, the adjusted line lies outside the 95% confidence limits for the FTP data. Figure 1 combines the data for port and throttle-body fuel-injected vehicles and no data are shown for trucks. Presumably, similar differences would be shown for the individual types of fuel injection and for trucks.

Thus, all the significant differences shown in Figures 1 and 2 in the M6.EXH.001 report are consistent with the hypothesis that there is some recruitment bias in the FTP data fleet. This recruitment bias generally leads to an underestimate of emissions.

The cases where there is no apparent recruitment bias are concentrated in the 1983-1987 model year vehicles. For this model year group only the NOx emissions in fuel-injected vehicles show a significant difference between FTP emissions and adjusted emissions. There is no apparent reason why this group of data should be relatively free of the hypothesized recruitment bias.

Based on these results, it is appropriate to conclude that significant differences occur between the Dayton fleet and the FTP data fleet. Once the conclusion that the fleets are different is reached, it is appropriate to adjust all the data, not just the data that are consistent with a recruitment bias. This was the procedure followed by EPA.

Cars tested with IM240 in Dayton are considered sufficiently representative of the national fleet, within each model year and technology grouping (M6.EXH.002)

There is no basis to attack or defend this statement. The data in the FTP fleet come from different studies. These data could be analyzed to determine whether there is a difference in the emissions performance of vehicles as a function of location. The absence of any difference in that data set would be an indication that vehicles from any single location would be “sufficiently representative” of the national fleet.

There are several possible differences that the fleet in any one location might have from the national fleet: age and type of vehicles, maintenance practices, mileage accumulation, distribution among vehicle manufacturers, effect of climate on vehicles. The analysis used for MOBILE6 accounts for different vehicle types and model years and for the effects of mileage. The Dayton data are intended to account for vehicle maintenance practices in areas without an I/M program. If there is an emissions difference from different manufacturers (e.g., domestic *versus* foreign) the Dayton fleet may not represent the national fleet. Finally, it is not clear what the differential effect of climate might be. There may be some interaction between climate and maintenance. Although these possible differences exist in principle, there are no data to determine whether they play a significant role in the representativeness of the Dayton data.

Odometer readings on individual Dayton vehicles are considered unreliable, and estimated mean odometer values are used instead (M6.EXH.002)

The report provides a qualitative discussion of the reasons for rejecting the procedure developed by SAI for correcting odometer readings, but does not show any quantitative results that justify the rejection of this process. The use of mean emission odometer readings is a significant problem in the analysis. This assumption ignores the distribution of mileage with vehicle age. The most dramatic display of this is in Figures 1 and 2 in M6.EXH.001; data for 1981 and 1982 vehicles occur at only two mileage points. It is likely that vehicles this old would have a broader spectrum of vehicle mileage.

The report states that the distributions of mileage obtained by using the probabilistic correction procedure developed by SAI were not realistic. However, no specific comparisons of a realistic distribution and a distribution found by the correction procedure are found in report M6.EXH.002. The SAI procedures were applied to the Dayton data and then the results were rejected in favor of mileage accumulation data for the local area.

It is not clear how significant this point is. One possible analysis is to recompute the high emitter correction factor using the original (adjusted) odometer data. If this showed no significant difference in the results, the use of the mileage accumulation data would have greater justification.

One possible alternative analysis is to use odometer and vehicle age data from other data sets. For example, CARB surveillance data sets, obtained under laboratory conditions, should have more careful recording of odometer data than is found in data from I/M lanes. Some odometer readings in the CARB data sets have been questioned because the odometers rolled over after 99,999.9 miles. Such readings can be checked using reasonable statistics and eliminated or corrected. Once a reasonable set of data is available, it can be modified to be applied to the Ohio data. (It may be necessary to consider that vehicle mileage can depend not only on vehicle age, but also on calendar year. I.e., the amount of vehicle use per year of operation, for a given vehicle age, may be changing over time. This effect is ignored in the discussion below.)

The alternative data could be represented as a set of empirical cumulative probability distribution functions. Each vehicle age would have such a distribution function. The distribution function would give the probability that the odometer reading was less than a certain value. To apply the alternative data to the Ohio data set, this distribution could be expressed as the ratio of odometer reading to mean odometer reading. An example of such a distribution is shown in the table on the next page. This hypothetical distribution assumes that the mean mileage for two-year-old vehicles is 30,000 miles. Such a distribution, regardless of the data source, could be compared with the Dayton data to see how well those data matched the typical distribution.

Hypothetical Odometer Distribution for two-year-old Vehicles									
Mileage Range	less than 9,000	9,000 to 15,000	15,000 to 21,000	21,000 to 27,000	27,000 to 33,000	33,000 to 39,000	39,000 to 45,000	45,000 to 51,000	greater than 51,000
Normalized Mileage Range	less than 0.3	0.3 to 0.5	0.5 to 0.7	0.7 to 0.9	0.9 to 1.1	1.1 to 1.3	1.3 to 1.5	1.5 to 1.8	greater than 1.8
Cumulative Probability	.02	.05	.1	.18	.3	.18	.1	.05	.02

Although the regression equations in MOBILE are based on odometer reading, the final results from that model are based on a distribution of odometer reading versus age that is the same for all vehicles. Thus, an age-based analysis is consistent with the overall approach used for the final results in MOBILE. Perhaps basic data sets should be analyzed in terms of vehicle age instead of odometer reading.

One problem with using vehicle age is that it is usually based on the model year. This has an uncertainty of one year. The I/M data from Dayton have the vehicle identification number (VIN) and may also have the vehicle license plate number. Either of these could possibly be used to determine the purchase date from the state agency that registers motor vehicles. This would give a more accurate measure of the vehicle age.*

*This may have already been done, but this detail is not presented in the M6.EXH.002 report.

Fast pass IM240 measurements in Dayton are converted to estimates of full IM240 (M6.EXH.002)

This appears to be a necessary step because there are no other data sets on late model year vehicles that provide measurements on vehicles that were not subject to I/M.* (I/M programs that use a 2% random sample of full 240-second tests are limited to areas with preexisting I/M programs.) The report discusses two possible regression approaches to converting the fast pass results into full IM240 data. The first approach, developed by EPA, uses several variables in a regression equation to predict the full IM240 results from the final fast pass results. The second approach, developed by Resources for the Future (RFF), uses regressions where the independent variables are the emission results at various time points in the test.

The EPA regression equation was derived from data obtained in the Wisconsin I/M program. The RFF approach was tested on data in the Arizona I/M program. Report M6.EXH.002 notes that "the EPA and RFF models produced similar mean estimates of full IM240 scores . . . Therefore, it was decided to use the values generated by the EPA approach." Although the two approaches produced similar results when *applied* to the Dayton data, there was no report of a *test* of the two approaches on the same set of data. Furthermore, for late model year vehicles, with very low emissions, the two approaches produce mean values that are off by more than 100%. It would be useful to compare the two approaches on the same data set to determine which one provides the better correlation.

The use of some regression analysis to obtain full IM240 results from the fast-pass data is a necessary step. The regression results displayed in the report indicate that the approach used by EPA provided R^2 values between 70% and 82% for the three pollutants. These are reasonably high R^2 values for emissions data.

It would have been instructive to compare frequency distributions for the full IM240 results in the (measured) Wisconsin data with similar results in the (fitted) Dayton data. If these distributions were essentially the same, the Wisconsin data could be used directly. There would be no need for the regression to get full IM240 results from fast-pass data. However, if the Dayton results had significantly different higher emissions (as expected), the use of the predicted full IM240 values from Dayton instead of the actual full IM240 values from Wisconsin would have further justification.

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*This is likely to be a problem in the development of data sets in the future. There is less likelihood that large data sets for in-use vehicles that have not been previous subject to I/M will be generated. It is not too early to start thinking about how the model equations for MOBILE7 will be developed in the absence of such data.

Estimates of full IM240 emissions are converted to estimates of running emissions (M6.EXH.002)

This conversion is based on a regression analysis of 997 vehicles of which 938 are from model years 1981 and later. (No other data were provided on this fleet; there was also no explanation of why the 59 vehicles from 1980-and-earlier model years were included in the regression intended for 1981-1993 model year vehicles.) Two steps are involved in this analysis. First, the FTP data are used to generate running emissions. This is the VMT-weighted sum of the bag two emissions and the hot running 505 emissions. The latter are found from the individual FTP bag data using the regression equations derived in the report M6.STE.002.

This step is necessary to obtain estimates of running emission results from the Dayton data. The R^2 values for these regressions range from 64% to 71%. The regression results in Table 4 of the M6.EXH.002 report list a value for the "Root MSE," which is another term for the standard error of the regression, $s_{y|x}$. For HC, the value of the Root MSE is 0.79242 for a regression equation with five parameters derived from a data set of 997 vehicles. The 95% confidence interval for the mean value of HC emissions at the point where each independent variable has its mean value for the regression data set is found as follows:

$$\begin{bmatrix} 95\%\ \mathit{Confidence} \\ \mathit{Interval\ for} \\ \mathit{mean\ HC\ value} \end{bmatrix} = \frac{\pm\, t_{0.025,\, 997-5}\ s_{y|x}}{\sqrt{n}} = \frac{\pm 1.962\ (0.79242)}{\sqrt{997}} = \pm 0.0492$$

This value is about 40% of the low-mileage emission level for fuel-injected vehicles and about 4% of the high mileage values for those vehicles, ignoring variation in the confidence limits with changes in the independent variables. As discussed in the section on overall conclusions, the confidence interval for the mean is the appropriate one to use for the MOBILE6 analysis where the regression equations are attempting to predict the emissions from the fleet. The use of such regression equations for single vehicles has a much larger confidence interval as shown below.

$$\begin{bmatrix} 95\%\ \mathit{Confidence} \\ \mathit{Interval\ for\ HC} \\ \mathit{predictions\ at\ mean} \end{bmatrix} = \pm\, t_{0.025,\, 997-5}\ s_{y|x} \sqrt{1 + \frac{1}{n}} =$$

$$\pm 1.962\ (0.79242) \sqrt{1 + \frac{1}{997}} = \pm 1.556$$

The presentation of confidence intervals (such as is done for the unadjusted data in Figures 1 and 2 of the M6.EXH.001 report) is a useful addition to the R^2 values that are generally reported for regression analyses in the reports reviewed here.

The weightings for the fraction of high emitters (based on the cars tested with IM240 in Dayton) are applied to the start emission estimates (M6.STE.002)

The procedure for determining the relative fractions of high and normal emitters is not discussed in any of the reports under review here. EPA did provide an Excel spreadsheet that showed that the fraction of high emitters was determined by computing three sets of running emissions (as a function of mileage): (1) the fleet average emissions (using the equations derived in M6.EXH.001), (2) the normal regime emissions, and (3) the high regime emissions. The fraction of highs, as a function of mileage, is then simply computed as follows:

$$\begin{bmatrix} High \\ Fraction \end{bmatrix} = \frac{\begin{bmatrix} Average \\ Emissions \end{bmatrix} - \begin{bmatrix} Normal \\ Emissions \end{bmatrix}}{\begin{bmatrix} High \\ Emissions \end{bmatrix} - \begin{bmatrix} Normal \\ Emissions \end{bmatrix}}$$

Report M6.EXH.001, discussed below, describes the determination of the equations for the fleet average emissions as a function of mileage. No specific information is provided in the four reports reviewed here on the determination of the equations for the normal and high regimes. According to statements on page twenty of the M6.STE.003 report, the emission equations for normal and high emitters were “estimated from the FTP data.” Without additional information it is not possible to comment on the validity of the equations used for the determination of the fraction of high emitters. However, based on the brief statement about the derivation of the high and normal emitter equations, the calculation of the high fraction seems to be based on inconsistent emission results. In the high fraction calculation, one term, the fleet average emissions, is based on FTP data corrected by the Dayton IM240 results. The other two terms in the high-fraction calculation, the normal and high emitter results, are based on FTP data alone. This apparent inconsistency should be addressed in the report that details the derivation of the high and normal emitter regime equations.

The assumption that the fraction of highs in start emissions is the same as the fraction of highs in running emissions is a good starting point for regime determination. It should be possible to check this assumption for the FTP data set* by comparing the high-running-emission vehicles with the high-start-emission vehicles. This could be done as follows.

1. From the analysis of high and normal emitters reported in the M6.STE.002 report determine the fraction of vehicles that are high emitters based on the FTP. Call this the high-emitter fraction.
2. Select the high-running-emission vehicles by taking the high-emitter-fraction of the vehicles with the highest running emissions.
3. Select the high-start-emission vehicles by taking the high-emitter-fraction of the vehicles with the highest start emissions.
4. Determine how much similarity there is between the two sets of vehicles selected in steps two and three.

If the vast majority of the high-start-emission vehicle set are also in the high-running-emission vehicle set, the assumption that both sets of high emitters are the same will have some quantitative justification.

The procedure outlined above would provide an alternative approach to selecting the high-start-emission data vehicles. Instead of selecting vehicles based on their FTP emissions, the vehicles that have high start emissions could be selected based on their start emissions alone. This could be done by taking a selected number of the vehicles with highest start emissions. This number could be selected by visual observation of the data, by using the same percent of vehicles that would be found by the FTP analysis, by selecting some arbitrary percentage, or by selecting vehicles with some arbitrary ratio of start emissions to average start emissions.

*The issue as posed by EPA states that the weightings for high emitters were based on the Dayton data. This is correct in that the running emission equations (based, in part, on the Dayton data) were used to calculate the fraction of high emittters. However, the analysis of the start emissions into high and normal regimes was based on an analysis of the FTP data sets only. Thus, it should be possible to check these data sets using the procedure outlined above.

REVIEW OF REPORT M6.STE.002

Scope of the Report

This report, entitled "The Determination of Hot Running Emissions from FTP Bag Emissions," plays a role in the determination of both start emissions and running emissions. It describes a straightforward study to obtain a regression equation that allows the prediction of an emissions mode not measured in the FTP – the hot running 505 – from conventional FTP measurements.

Comments on Overall Clarity

The overall clarity of the report is generally good. Four minor suggestions for improvement are listed below.

On page two, the second paragraph from the bottom references an "accompanying EPA document entitled 'Determination of Start and Running Emissions Deterioriation.'" There is no reference for this "accompanying document." This comment should be replaced by a specific reference to another report reviewed here, M6.EXH.001. In fact, this report is best seen as an adjunct to M6.EHX.001. The latter report contains a good description of the FTP and the need for the hot-running 505 cycle.

The third paragraph on page three says that the test program data are shown in Table 1. However, Table 1 does not contain the data on the hot running 505 emissions. It only contains the conventional FTP bag data.

On page four, the "logarithm transformation constant" is mentioned. An appropriate reference should be provided for readers who are not familiar with this concept. The discussion of this constant states that the transformation constant is "implicit" in the regression equation constant, D. Table 3a presents a value for both D and the log transformation constant. It is not clear from the "implicit" sentence on page four whether or not the value of D in Table 3a already contains the constant. This should be stated in the table. (If the value of D does not contain the constant, the report should state whether the log transformation constant is to be added to or subtracted from the value of D shown in the table.)

The appendices to the report should be deleted. These contain the statement of work for the contractor who recruited and tested vehicles to obtain the results for a variety of cycles, including the hot running 505 cycle data. Instead, a table should be added to the body of the report showing the characteristics of the 77 vehicles used in the regression. This should be a summary table, similar to those in the other reports reviewed here. These tables show how many vehicles from each technology group were used in the study. (Such a table for this study will have to include technology groups that are outside the 1981-1993 model years discussed in the other reports.)

General Review of the Overall Methodology

The scope of this report is the development of a regression analysis that relates the hot running 505 emissions to other data that are generally available: vehicle data and bag-by-bag emissions data from FTP tests. This analysis was discussed above, starting on page 6.

Two of the vehicles shown in Table 1 – vehicles 221 and 223 – have zero emissions for bag two. These were presumably not used in the logarithmic regressions. This could be included in a footnote for the data analysis section of the report.

The results of this regression analysis will be used to predict the hot running 505 emission results from other vehicles. It would be useful to show the confidence limits for the future prediction. Since these confidence limits depend on the values of the independent variables for the future predictions, the limits could be shown as the minimum values that occur when each of the independent variables is at its mean value. This would give the reader a better indication of how accurate the future use of the equation for predictions will be. This uncertainty is likely to be large, but if it is applied to a large number of vehicles in future predictions, the uncertainty for the mean of those future predictions will be small.

Other Comments

The data set analyzed in this report was developed specifically for this study. This reviewer is not aware of any other data sets that could be used for this regression analysis.

The resulting data set used in this analysis has several vehicles with negative start emissions, i.e., vehicles for which the hot running 505 emissions are greater than bag one or bag three. This is likely due to measurement error rather than reduced emissions from starting phenomena. Such data points should be kept in the analysis to avoid bias from removal of data points with negative errors without removal of corresponding data points with positive errors.

The data taken are appropriate ones for obtaining such a correlation. The vehicles used in the data set are only described in a qualitative manner. Based on that limited description, the vehicles selected for the data set seem appropriate.

The essential conclusion for this report is that a satisfactory regression equation giving hot running 505 emissions as a function of FTP test data has been developed. This seems to be an appropriate conclusion. Various suggestions made above for possible alternative approaches are likely to have only a small effect on the final equations.

REVIEW OF REPORT M6.STE.003

Scope of the Report

This report, entitled "Determination of Start Emissions as a Function of Mileage and Soak Time," is a key document; it describes the methods used to obtain the equations proposed for computing start emissions in MOBILE6. The analysis used here divides the fleet into normal and high emitters and determines the start emissions as a function of mileage for both emitter regimes. The effect of soak time on start emissions is determined by a modification of a similar relation devised by the California Air Resources Board.

The effect of mileage on start emissions is found by a regression analysis, but the statistical results of this analysis are only briefly mentioned. No details of the regression statistics are presented. Start emissions are defined as the difference between the portions of the FTP with starts – bag one with a soak (engine-off) time of twelve hours and bag three with a soak time of ten minutes – and the equivalent driving conditions without a start. Data for the no-start driving conditions, called the hot running 505, is found from the regression equations discussed in the M6.STE.002 report.

Comments on Overall Clarity

The specific task considered in this report is reasonably well described. The sections on the FTP weightings and the sample calculation of start emissions are particularly clear. However, it is difficult to see how this report fits into the overall scope of the MOBILE6 emissions equations. This difficulty is caused by the interaction of the subject of this report with the processes used for computing running emissions. An overview report describing the entire process for obtaining the start and running emissions would be helpful.

Some suggested editorial changes and typographical errors are listed below.

In the second paragraph on page two, the descriptions of sections four and five are reversed.

On page six, the first sentence in the third paragraph from the bottom states that the "high/normal emitter modeling concept . . . is discussed in detail in other reports." It would be useful to have a specific reference. In particular, the set of four reports reviewed here does not present the derivation of the running emission equations for normal and high emitters. These equations, along with the equation for average running emissions developed in the M6.EXH.001 report, are used to compute the fraction of high emitters as a function of mileage.

The discussion of the conversion from the CARB soak function to the EPA soak function is difficult to follow. This is due, in part, to the fact that the discussion involves a ratio of ratios, always a difficult subject to describe verbally. In particular, the "Ratio" term defined on page ten of the M6.EXH.003 report is actually the following ratio of ratios:

$$\frac{\left[\dfrac{EPA\ \ Start\ \ Emissions\ \ at\ 10\ \ minutes}{EPA\ \ Start\ \ Emissions\ \ at\ 720\ \ minutes}\right]}{\left[\dfrac{CARB\ \ Start\ \ Emissions\ \ at\ 10\ \ minutes}{CARB\ \ Start\ \ Emissions\ \ at\ 720\ \ minutes}\right]}$$

This appears to be different from the definition of the "Ratio" term used by EPA. That definition uses the CARB soak function at 720 minutes instead of the CARB emission ratio. However, the CARB soak function is defined as the emission ratio shown in the equation above.

Although the results of the soak function proposed in the report are clear, some text, such as the following, would be helpful to readers who wonder how the correction was derived:

> The CARB soak function was adjusted by a set of piecewise linear correction factors. These correction factors were set so that the correction factor was one for soak times of zero and the maximum soak time for the first domain of the CARB soak function. In addition, at a soak time of ten seconds the correction factor was defined to give the same ratio for start emissions found in the EPA data. The two analyses were combined by the defining an "X term," which has different values for different linear regions.

This comment may not add any more clarity to the discussion, but it may be helpful to readers who want to understand how the final soak function was developed. (See the comment below under methodology requesting clarification for some choices made in the development of the correction to the soak function.)

On page eleven the last line says that the start emissions are at 90 minutes instead of the correct value of 88 minutes.

General Review of the Overall Methodology

There are five basic steps used to determine start emissions as a function of mileage and soak time.

1. The start emissions are defined as the difference between the bag one (or bag three) data and the hot running 505 data. (The latter is found from the regression analysis developed in report M6.STE.002.)

2. Each technology group is characterized by two regimes: high and normal emitters. The fraction of high emitters for start emissions, in the actual fleet, is assumed to be the same as the fraction of high emitters for running emissions, in the actual fleet.

3. The high emitters in the data fleet were selected on the basis of the overall FTP emissions rather than the start emissions.

4. Regression analyses were used to determine start emissions as a function of mileage for a soak time of 720 minutes.

5. The effect of soak time on start emissions was obtained by using a modification of the CARB soak function. This was based on data obtained on start emissions for soak times of ten minutes and 720 minutes.

This overall approach seems reasonable given the data sets that were available. The definition of start emissions is appropriate. The report does not discuss any details of the data. In particular, did any of the vehicles have negative start emissions? If so, how were these data handled? From subsequent discussion of the results for high emitters it appears that negative start emissions data were correctly handled; i.e., these negative values were not eliminated before performing the regressions.

The authors elected not to present statistical results in the report because of the amount of data. This contrasts with other reports in which such data were presented. Table 4 in the report contains the regression coefficients for normal emitters for all twelve technology groups. This one-page table could be expanded to three pages, one for each pollutant, with the addition of five regression statistics for each row in the table: the sample size, n, the value of R^2 and $s_{y|x}$ for the regression, and the standard error for the slope and intercept.[*] Similarly, the sample size and the standard deviation for HC

[*] Instead of the standard errors the tables could contain the probability that the coefficient is zero, a statistic used in the M6.STE.002 report.

and CO start emissions could be added to Table 5. This would give a reasonable picture of the statistics for these equations without an undue increase in the report size.

The effect of soak time on start emissions was done by a modification of the CARB soak functions. These are empirical equations giving the ratio of start emissions at any soak time, t, to the start emissions for a soak time of 720 minutes. These empirical functions are expressed as quadratic functions of soak time for two separate time domains: a low time from zero to about 100 minutes and a high time from about 100 seconds to 720 minutes.* The modification of these functions basically provides a multiplicative correction factor that satisfies the following conditions:

1. The EPA and CARB soak functions provide the same values for soak times of zero and soak times of 720 minutes.
2. For a soak time of ten minutes the EPA soak function provides the value that is based on the ratio of start emissions found by EPA. *I.e.*, the ratio of start emissions for a soak time of ten minutes to start emissions for a soak time of 720 minutes, provided by the EPA soak function, is the same as the values EPA measured for this ratio.

In the conversion from the CARB soak function to the EPA soak function two decisions were made which were not explained in the report. The first of these was the decision to have the EPA soak function equal to the California soak function for the entire soak time domain of the second empirical equation. The second decision was to use only a single value for the ratio of start emissions (ten-minute soak time emissions divided by 720-minute soak time emissions) for all control system types.

Although these choices are not explained, they are reasonable ones to make. The decision to apply the correction only to the short soak time equation was most likely made so that the EPA data on ten-minute soak times would provide a correction for short soak times, but would not create any corrections far from the ten-minute data point. The decision to use only a single value for the ratio term was probably done because of a lack of data on noncatalyst and electrically-heated-catalyst vehicles. The reasons for these choices should be explicitly stated in the report.

Other Comments

The use of the FTP data set is appropriate for this analysis and this reviewer is not aware of any additional data sets that could be used. The Dayton data set used to correct the running emissions does not have cold start data and could not be used for the high-emitter correction factor as it was for running emissions.

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*The actual boundary point between the low soak time and the high soak time domain depends on the pollutant and the emission control system used.

Additional comments on using the fraction of high emitters found from the running emissions data have been presented in the section on issues for which EPA requested comment. Those comments propose an additional analysis to confirm the assumption that the fraction of high emitters is the same for both the start and running emissions.

The implied conclusion of this report is that an equation has been developed to model the start emissions of 1981-1993 light-duty vehicles as a function of mileage and soak time. This appears to be an appropriate conclusion, but it would be useful to have some measure of the statistical uncertainty in the final prediction equation.

REVIEW OF REPORT M6.EXH.001

Scope of the Report

This report, entitled "Determination of Running Emissions as a Function of Mileage for 1981 - 1993 Model Year Light-Duty Cars and Trucks," provides the basic analysis used to obtain running emissions as a function of vehicle mileage. The running emissions are defined as the sum of the bag two emissions plus the hot running 505 emissions. The latter are found by the regression analysis defined in the M6.STE.002 report.

The first step in this report is the derivation of running emissions as a function of vehicle mileage using data on FTP emission results. EPA was concerned that the vehicles recruited for this fleet may be a biased sample: vehicles that owners do not submit for the voluntary test programs will have different emissions characteristics from those submitted. To address this concern, data from IM240 measurements are used to adjust the FTP equations. The IM240 data should be free from the sampling bias, but the results from this simple test have to be adjusted to get the equivalent FTP emissions rates from the IM240 data.

The final result from this report is a set of equations giving the running emissions as a function of vehicle mileage for various technology groups.

Comments on Overall Clarity

The overall clarity of the report is good. Additional points of clarification, editorial suggestions, and typographical errors are listed below.

The equation near the top of page five does not readily follow from the preceding discussion. Since the discussion describes the running LA4 emissions as the combination of two driving cycles, it would be clearer to define the weighting factors as the mileage for each of these cycles: 3.59/7.5 = .479 for the hot running 505 emissions and 3.59/7.5 = 0.521 for the bag two emissions.

On page six, the description of case 2b (three lines in the piecewise linear function) does not fully specify how the final emission *versus* mileage relation is found. The process is more clearly explained in the note on Table 3. The discussion of constrained and unconstrained lines at the top of page six could be merged with the discussion in the numbered and lettered paragraphs in the second half of the page to provide a clearer presentation of the *details* of various cases.

The description of the derivation of the data for the high-emitter correction factor is not clear. The first new paragraph on page eight says that the mean running LA4 values were plotted as a function of mileage and smoothed "in the manner required for use in MOBILE6." From email correspondence with Phil Enns, one of the report authors, it appears that the smoothing was done by a regression analysis. The details of this "smoothing" analysis should be presented in the report.

The minor divisions for mileage on Figures 1 and 2, 4 and 2 kilomiles, respectively, could be more convenient if they were replaced by 5 and 2.5 kilomiles, respectively.

The note to Table 4 could be reworded to emphasize that the "adjustment additive" shown in the table has already been included in the slope. At first reading, it appears that this final column needs to be added to the results obtained from the previous columns.

Other Comments

The issues on which EPA requested comment include several major points of the overall methodology used in this report: the use of piecewise linear functions, the correction of FTP data by the Dayton data and the use of mileage accumulation figures instead of odometer readings for the Dayton data. That section contains several comments on the details of the process used with suggestions for clarification and improved justification of some choices made in the process. However, the overall method used to arrive at the running emission equations, including the data sets used, is appropriate.

REVIEW OF REPORT M6.EXH.002

Scope of the Report

This report, entitled "Analysis of Emissions Deterioration Using Ohio and Wisconsin IM240 Data," describes two sets of regressions used to obtain deterioration rates in the previous report, M6.EXH.001:

1. a regression from fast pass IM240 scores to full IM240 scores, and

2. a regression from IM240 scores to running LA4 emission rates.

The first regression provides a means for converting the fast pass IM240 scores available from the Dayton IM240 data sets into full IM240 results. (The Dayton data do not have a random 2% sample for the full IM240 tests.) Data from Wisconsin that do have the random 2% of full 239-second tests are used to obtain the regressions that relate fast pass results to full IM240 results. (The Dayton data were preferred to the direct use of the Wisconsin data because Dayton did not have a preexisting I/M program.)

One important step in this report is the treatment of mileage data. Because of problems with the accuracy of odometer readings, vehicle mileage was based on typical mileage accumulation data, as a function of vehicle age, in place of odometer readings.

The second regression – from IM240 scores to running LA4 exhaust results – is based on data obtained in Hammond and Phoenix. No details of the fleet used for this regression are reported except the statement that 938 of the 997 vehicles are from model years 1981 and later. The authors presumably felt that the increased sample size was more important than a better match of the fleet characteristics; otherwise, the 59 vehicles from 1980 and earlier model years could have been excluded from the data set.

Comments on Overall Clarity

It would be helpful to have an abstract summarizing the purpose and results of the report: the derivation of two sets of regression equations. The title of the report is misleading. Although the regression equations used in this report are aimed at an analysis of emissions deterioration, the actual deterioration analysis is presented in another report, M6.EXH.001.

The report does not provide any quantitative justification for rejecting the corrected odometer data. On page five the following sentences describe the decision to reject corrected odometer data and use mileage accumulation data in their place:

> While [corrected odometer data were] not an ideal solution, it was felt that this method yielded an improvement to the uncorrected odometer values in the raw data. After reviewing the corrected odometers, however, a decision was made to use region-specific mileage accumulations instead for subsequent analysis.

Since this decision is such a significant one, it deserves more explanation and justification.

In addition the following points of clarification or typographical errors were noted.

In Table 2 the variable named FSEC (which is highly significant in the regression) is not defined.

The report does not indicate if all the regressors shown in Tables 2 and 4 were used in the final regression equation. Were all the terms that appear in Tables 2 and 4 used regardless of their significance (as was done in the M6.STE.002 report)? Was the same adjustment for bias resulting from the log transformation, which was used in the M6.STE.002 report, used here? If so, what was the final value for the constant term? Why were the D_i and D_i (LFxx) coefficients in Table 2 not shown -- was this done to save space or were these coefficients not significant?

In Table 4 one of the independent variables is erroneously listed as LFxx. It should be listed as LxxIM, the natural log of the IM240 gram/mile result.

Other Comments

The main concern with the overall methodology was with the use of mileage accumulation data. This was discussed in the section on specific issues. Other than this, the overall methodology is appropriate for the task at hand. The regression methods used here appear correct and the data sets used are generally appropriate for the required analyses.

CONCLUSIONS

Based on this review, the overall approach taken in the four reports reviewed provides a reasonable method for the computation of start and running emissions of HC, CO and NOx for 1981-1993 light-duty vehicles. The significant issues that require further justification or analysis are the use of the mileage accumulation based on vehicle age for the Dayton data and the computation of the high emitter fraction.

In the instructions for this review, EPA asked for a distinction between "recommendations for clearly defined improvements that can be readily made based on data reasonably at hand to EPA, and improvements that are more exploratory or dependent on data not available to EPA."

Most of the comments in this review have addressed the clarity of the reports and the suggestions for additional statistical results and additional justification, particularly quantitative results, for some choices made in the various reports. All the recommendations in this category could be done with data on hand. Many of these suggestions have been made with the sense that the reports under review are progress reports and that EPA will prepare a final report describing the overall preparation of MOBILE6. If this is correct, the suggested additional analyses could be deferred until the preparation of that report.

The discussion on the use of mileage accumulation rates on the Dayton data suggested that this could be a major concern in the development of the final equations. Suggestions for providing additional justification for the final choice could be done by reporting more results of the analyses that led to the choice of using mileage accumulation rates. This should not require any additional data sets. Two suggestions, one for an alternative analysis using different data sets on mileage as a function of vehicle age and the second to consider an analysis for MOBILE based only on age, using actual purchase dates to compute age where available, are intended to be more exploratory in nature. Similarly the footnote on page 13, which discusses the possible need for an alternative data approach for MOBILE7, is intended for a future version of the model.

The method for computing the fraction of high emitters was not presented in the four reports presented here and is not formally under review. However, as noted on page 15, the discussion of the approach taken suggests that there may be an inconsistency in the emissions equations used for the computation of this fraction. This should be addressed in the report that presents the equations used to compute the emissions of high and normal emitters as a function of odometer reading.