United States Environmental Protection Agency
Air and Radiation
EPA420-R-01-021
April 2001
M6.EVP.005

Modeling Diurnal and Resting Loss Emissions from Vehicles Certified to the Enhanced Evaporative Standards

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ABSTRACT

This report documents the method used in MOBILE6 for estimating the resting loss and diurnal emissions from vehicles certified to the enhanced evaporative standards (i.e., 1999 and newer vehicles plus some 1996 through 1998).

This report was originally released (as a draft) in November 1998. This current version is the final revision of that draft. This final revision incorporates suggestions and comments received from stakeholders during the 60-day review period and from peer reviewers.

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Modeling Diurnal and Resting Loss Emission from Vehicles Certified to the Enhanced Evaporative Standards

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1.0 INTRODUCTION

Evaporative emissions of hydrocarbons (HC) are a significant portion of the total HC emissions estimated in the MOBILE model. In two parallel reports (M6.EVP.001 and 002), the Environmental Protection Agency (EPA) identified the methods that are being used in MOBILE6 to estimate resting loss and diurnal emissions from 1995 and older model year vehicles. These estimates are based on the results of real-time diurnal (RTD) tests of in-use vehicles in which the ambient temperature cycled over a 24-degree Fahrenheit range to simulate in real-time the daily heating and cooling that parked vehicles experience over a 24-hour period.

Beginning with the 1996 model year, manufacturers were required to certify at least twenty percent of their vehicles using a new "enhanced" evaporative testing procedure (ETP); that percentage of ETP vehicles was required to increase from the twenty percent in 1996 up to one hundred percent by 1999. The actual phase-in of these ETP vehicles proceeded at a slightly faster pace (based on EPA's analysis of data from the Wisconsin Inspection/Maintenance program for model years 1996-1999). The phase-in rate required by the regulations* is given in Table 1 (below) along with the observed (actual) phase-in rate.

Table 1

Phase-In of Vehicles with Enhanced Evaporative Controls

Model Year	Required * Percentage	Observed Percentage
1995	0%	0%
1996	20%	30%
1997	40%	55%
1998	90%	90%
1999	100%	100%

* The percentages for the "required" phase-in were copied from **40 CFR 86.096-8**

EPA expects that these ETP vehicles will have evaporative emissions different than their pre-1996 (pre-ETP) counterparts (thus, requiring distinct estimates). This assumption is based on a number of changes that the manufacturers have implemented in order to meet the enhanced evaporative standards. These changes include, but are not limited to:

- "quick connects" that reduce the possibility of improper assembly when the vehicle is serviced,
- advanced materials that are less permeable, less susceptible to puncture, and more durable (i.e., elastomeric materials used in hoses and connectors),
- improvements made to the purge system (to enable the vehicles to pass both the running loss test and the multi-day diurnal test),
- tethered gas caps, and
- improved fractional-turn gas caps.

Since these changes are expected to result in improved control of evaporative emissions, EPA used in MOBILE5, a separate set of estimates for both resting loss and diurnal emissions from these vehicles.

In the original analyses that supported this rule, EPA estimated that by requiring vehicles to meet these enhanced evaporative standards the following would result:

- for those ETP vehicles with properly functioning evaporative control systems (i.e., vehicles passing both the purge test and the pressure test), full-day diurnal emissions would be reduced by 50 percent compared to the corresponding pre-ETP vehicles,
- for those ETP vehicles with malfunctioning evaporative control systems (i.e., vehicles failing either the purge test or the pressure test), there would be no reduction (zero percent) of full-day diurnal emissions compared to the corresponding pre-ETP vehicles, and
- for all ETP vehicles, resting loss emissions would be reduced by 75 percent compared to the corresponding pre-ETP vehicles.

In the previous version of the MOBILE model (i.e., MOBILE5), EPA used these estimated reductions to characterize the diurnal and resting loss emissions of the ETP vehicles. EPA also used the required phase-in rate (middle column in Table 1) to describe the distribution of the ETP vehicles among the 1996-98 model year vehicles in the in-use fleet.

The goal of the analyses in this report was to review and possibly replace those MOBILE5 hypotheses in the light of additional data. Implementing this goal involved determining the following three items:

(1) the percentage of ETP vehicles for each of the phase-in model years (1996-98),

(2) the emissions (resting loss and diurnal) of these ETP vehicles (see Sections 4.1 and 4.2), and

(3) the percentage (by age) of vehicles with properly functioning evaporative control systems (see Section 5).

The first of these three items was relatively straightforward. EPA chose to use the observed phase-in rate (third column in Table 1), rather than the rate specified in the regulations, to describe the percent of ETP vehicles for the 1996-98 model years in the in-use fleet.

The parallel analyses (report M6.EVP.001) of the diurnal and resting loss emissions for pre-enhanced (i.e., pre-1996 model year) vehicles are based on results of tests of actual in-use vehicles. However, the analyses in this report generally are <u>not</u> based on testing of actual in-use ETP vehicles because EPA has very few test results on that segment of the in-use fleet. In this report, EPA explores methods of estimating the resting loss and diurnal emissions from these in-use 1996 and newer vehicles based primarily on RTD testing of older (pre-ETP) but similar vehicles.

Since many of the estimates (developed in the report) of resting loss and diurnal emissions for the ETP vehicles in MOBILE6 are based on pre-ETP vehicles, EPA will likely revisit these estimates when sufficient test data on actual ETP vehicles become available.

2.0 DATA SOURCES

In the parallel analyses (report M6.EVP.001) on the pre-ETP (i.e., 1995 and earlier model year) vehicles, EPA based its estimates of resting loss and diurnal emissions on the results of real-time diurnal (RTD) tests on 270 in-use vehicles. However, at the time of this analysis on the 1996 and newer vehicles, EPA had only two available sources of RTD test data on vehicles that were certified to the new evaporative standards:

1) results of RTD testing used by the Air Resources Board (ARB) of California and by the EPA (30 and 35 vehicles, respectively) to certify new ETP vehicles (1996-97 model year) (see Appendix A) and

2) results of RTD testing performed by Mercedes-Benz on six of its 1996 model year vehicles (at two years of age) as

part of the proposed Compliance Assurance Program (CAP 2000) (see Appendix B).

However, these test data (from these two sources) on the 1996 and newer vehicles have three serious limitations:

- First, all of the 1996 and newer vehicles from these two sources had properly functioning evaporative control systems. Since it is likely that some similar in-use vehicles during the course of their useful life would develop malfunctions in their evaporative control systems, any analysis restricted to these data sets would be limited by not including test results on such malfunctioning in-use vehicles.

- Secondly, all of these RTD tests were performed using a single test fuel with a Reid vapor pressure (RVP) of 9.0 psi and using a single temperature cycle (72 to 96 degrees Fahrenheit). Thus, using only these data, it would be not be possible to predict evaporative emissions at other combinations of temperature cycle and fuel volatility.

- Finally, the RTD test data on all 65 of these vehicles were reported in the form of full-day (not hourly) emissions. However, EPA's procedure of estimating the resting loss portion of the emissions requires the hourly RTD emissions (at least for hours 19 through 24); thus, EPA could not use these data to estimate resting loss emissions.

To compensate for those significant limitations, EPA supplemented those data with the results of RTD testing of older vehicles (used in M6.EVP.001) that were not certified to the enhanced evaporative standards. Two sources of those additional RTD test results were:

3) RTD testing performed on 119 in-use 1971-95 model year vehicles for EPA by its testing contractor and

4) RTD testing performed on 151 in-use 1971-91 model year vehicles for the Coordinating Research Council (CRC).

Although none of those 270 in-use vehicles tested in the EPA or CRC programs (sources 3 and 4) had been certified to the new evaporative standards, the combined sample does include both:

- in-use vehicles with malfunctions in their evaporative control systems

as well as

- vehicles for which the RTD test was performed over three different temperature cycles and using fuels with at least two different RVPs.

Obviously, it would be inappropriate to use test data from all 270 of those vehicles. Only a few of the newest vehicles in that sample are likely to be comparable to the actual ETP vehicles. (Section 3 deals with the selection of that sub-sample.)

In Section 3.0, EPA discusses how it used RTD test results from some of the older (i.e., 1990-95) vehicles (i.e., from sources 3 and 4) to compensate for the limitations of the test results on the 1996 and later vehicles.

3.0 SIMULATING TEST DATA FROM IN-USE 1996 AND NEWER VEHICLES

The MOBILE model must be able to estimate the resting loss and diurnal evaporative emissions from the 1996 and newer model year ETP vehicles over a variety of daily temperature cycles and with a variety of fuel RVPs. However, as noted in the preceding section, the only test data on those vehicles available at the time of this analysis are with a single combination of fuel volatility (RVP of 9.0 psi) and daily temperature profile (i.e., ambient temperatures cycling between 72 and 96 degrees Fahrenheit). EPA, therefore, used the results of RTD tests on pre-ETP vehicles (i.e., model years 1990 through 1995) to estimate the effects on the actual "base line" emissions (from source 1) of different fuel volatility and different temperature cycles on the resting loss and diurnal evaporative emissions of the 1996 and newer vehicles.

For the purpose of characterizing the effects of varying the fuel RVP and/or the temperature cycle, EPA will continue (from the parallel analyses) the approach of dividing the in-use fleet into the following four strata:

1) The first of these four strata consists of vehicles having substantial leaks of liquid gasoline (as opposed to simply vapor leaks); these vehicles were labeled "gross liquid leakers."

   EPA proposed (in M6.EVP.001) using as a definition for such vehicles the requirement that the hourly resting loss (at 72 degrees Fahrenheit) be at least 1.0 grams per hour of HC. EPA realizes this definition needs to be amended to include vehicles having substantial leaks that are apparent only when the engines are operating (e.g., some fuel line leaks). (See parallel report number M6.EVP.009 entitled "Evaporative Emissions of Gross Liquid Leakers in MOBILE6.")

2) The second of these four strata consists of vehicles (not "gross liquid leakers") that pass <u>both</u> the purge and pressure tests (i.e., vehicles with properly functioning evaporative control systems).

3) The third of these four strata consists of vehicles (not "gross liquid leakers") that fail the pressure test (regardless of their performance on the purge test).

4) The fourth of these four strata consists of vehicles (not "gross liquid leakers") that fail <u>only</u> the purge test.

While neither the purge test nor the pressure test (which are each being used to determine the stratification) actually measures evaporative emissions, a failure of the vehicle on either test is indicative of potential malfunctions of the vehicle's evaporative control system. Additionally, the recruitment of the vehicles in the third data source was intentionally skewed to recruit a larger proportion of vehicles with potentially malfunctioning evaporative control systems (i.e., a stratified random recruitment). Therefore, the results of any analysis must be weighted to correctly represent the entire in-use fleet. Thus, the analyses will be stratified to match the recruitment process.

As discussed previously, it was necessary to make use of the RTD tests performed on older (1990-95 model year) vehicles to predict the effects on the evaporative emissions of changes to the temperature cycle or the fuel RVP. In order to make use of those RTD tests on some of those 270 vehicles, EPA made the following assumptions:

1) The 1996 and newer vehicles are expected to be port fuel injected (PFI); therefore, EPA chose the 1990 to 1995 model year vehicles that were equipped with PFI as appropriate surrogates.

2) To simulate the ETP vehicles with properly functioning evaporative control systems, we then selected a subset (of those 1990-95 model year vehicles equipped with PFI) that passed both the purge test and the pressure test. The resulting 25 vehicles are listed in Appendix C.

   EPA believes that not all the vehicles in this sample of 25 pre-ETP vehicles (Appendix C) are appropriate for simulating the actual ETP vehicles. Examining the sample of 65 actual ETP vehicles in Appendix A, we note that the first-day diurnal emissions range between 0.340 and 1.675 grams, with a mean of 0.745 and a median of 0.635.

   We then restricted those 25 vehicles in Appendix C to those having the first-day diurnal emissions of at most 1.7 grams (using a fuel with an RVP of 9.0 over a 72-96 temperature cycle), producing the seven vehicles listed in Appendix D (all with multiple tests). This seven-vehicle sub-sample has a mean full-day diurnal of 0.902 grams and a median of 0.741. (While EPA used this seven-vehicle sample in its analyses, another analyst could more closely approximate both the mean and median in Appendix A by further restricting the first-day diurnal emissions to no more than 1.0 grams instead of 1.7. The resulting (smaller) five-vehicle sub-sample has a mean of 0.726 and a median of 0.653. However, EPA believes that the advantages of the somewhat larger sample size outweigh the advantages of the slightly improved statistical fit.) An additional three vehicles can be added by applying that 1.7 gram limit to vehicles tested only on a fuel with an RVP of 6.8 psi (resulting in the total of 10 vehicles listed in Appendix D as being possible "ETP-like").

Since the goal of this analysis is to predict the resting loss and diurnal emissions over a range of temperature cycles and fuel RVPs, we limited our analyses to the seven vehicles in Appendix D that were tested over a range of temperature cycles.

3) EPA believes that the RTD emissions from malfunctioning enhanced evaporative control vehicles (i.e., vehicles that developed problems with their evaporative control systems) will be similar to the RTD emissions from the 1990 to 1995 model year vehicles that also develop problems with their evaporative control systems. That is, those 1996 and newer model year vehicles that had failed either EPA's purge or pressure tests are expected to have evaporative emissions similar to those 1990 to 1995 model year PFI vehicles that also failed the same test.

   Thirteen such vehicles were identified in the combined EPA/CRC sample (eight of them failing only the purge test and the remaining five failing the pressure test). (See Appendices E and F, respectively.) EPA used the RTD tests on these 13 vehicles to estimate the temperature and fuel RVP effects on resting loss and diurnal emissions for ETP vehicles that have malfunctioning evaporative control systems.

4.0 ANALYSIS

As noted in two parallel reports (M6.EVP.001 and M6.EVP.002), EPA is using (in MOBILE6) the results of the RTD test to model two distinct mechanisms of evaporative emissions:

1) "Resting loss" emissions are always present, regardless of vehicle activity, and are relatively weakly related to the ambient temperature as opposed to diurnal emissions that are related to the rise in temperature.

   The earlier reports calculated the hourly resting loss emissions to be the mean of the RTD emissions from hours 19 through 24 at the nominal temperature for hour 24. This method permitted EPA to estimate the hourly resting loss emissions at three distinct temperatures (60, 72, and 82 degrees Fahrenheit). In those analyses, resting loss emissions were determined to be independent of the RVP of the test fuel.

2) "Diurnal" emissions are the pressure-driven emissions resulting from the daily increase in temperature.

The diurnal emissions were calculated by first estimating the resting loss value for the ambient temperature at each hour of the 24-hour cycle, and then subtracting that temperature-adjusted resting loss estimate from the RTD hourly test results.

In those two parallel reports, this approach permitted EPA to use the RTD test results to analyze separately both the relatively constant resting loss emissions and the (pressure driven) diurnal emissions.

4.1 Resting Loss Emissions

In the parallel analyses of the resting loss emissions of the pre-ETP vehicles (report M6.EVP.001), EPA used regression analyses of the resting loss emissions (at three temperatures) to model the resting loss emissions. This approach was repeated in the previous draft version of this report (i.e., the version reviewed by our stakeholders and by two formal peer reviewers).

4.1.1 Resting Loss Emissions of Properly Functioning Vehicles

EPA initially (i.e., in the previous draft version of this report) selected from Appendix C the (averaged) three resting loss emissions from the seven vehicles that had been tested over three temperature cycles. This yielded the following table of results.

Table 2

Mean Hourly Resting Loss Emissions For Seven "ETP-Like Vehicles" (grams/day)

Vehicle Number	Temperature (degrees F) 60	72	82
5032	0.0045	0.0070	0.0150
5038	0.0033	0.0053	0.0093
5046	0.0075	0.0100	0.0305
5047	0.0050	0.0120	0.0150
5066	0.0000	0.0050	0.0075
5068	0.0060	0.0095	0.0235
5081	0.0050	0.0040	0.0090
Mean	0.0045	0.0075	0.0157
Std. Dev.	0.0024	0.0030	0.0085

In the previous analyses, EPA then performed regression analyses to model those three mean resting loss emissions (grams/hour) (from the preceding table) as a function of temperature. After the draft was released (for comments), it was noted that:

1. The sample size is quite small.
2. The estimated hourly emissions are close to the limit that the equipment can measure.
3. The vehicles are not true ETP vehicles, they only simulate what we expect from ETP vehicles.
4. If we estimate the hourly resting loss of comparable pre-ETP vehicles (using the equation from M6.EVP.001) and then compare those estimates to the means in the preceding table, we find that these means are reductions of 75 to 85 percent of the pre-ETP estimates. (This is consistent with the final "bullet" on page 2, which is a re-statement of the conclusion reached in the original regulatory analysis.)

Base on these four points (especially the last two), EPA revised its approach to estimating the resting loss emissions from the properly functioning ETP vehicles. Rather than use the new equation derived in the earlier draft version of this report, EPA chose to simply apply the previously estimated reduction factor of 75 percent to the equation for the comparable pre-ETP vehicles (from M6.EVP.001). This produces equation **(1)** below:

$$\textbf{Hourly Resting Loss (grams/hr)} = -0.035168 + [0.000703 * \textbf{Temperature (°F)}] \qquad \textbf{(1)}$$

EPA uses (in MOBILE6) equation **(1)** to estimate the hourly resting loss emissions (in grams per hour) of that portion of the fleet of ETP vehicles with <u>properly</u> functioning evaporative control systems.

Equation **(1)** predicts that the mean hourly resting loss emissions (for the fleet of 1996 and newer model year vehicles with properly functioning evaporative control systems) would be negative for all ambient temperatures below 50.1 degrees Fahrenheit. EPA will (in MOBILE6) assume, that for each of the hours of the day that those temperatures occur (i.e., hourly temperature < 50.1 F), the resting loss emissions will be set to zero grams.

4.1.2 <u>Resting Loss Emissions of Malfunctioning Vehicles</u>

To estimate the resting loss emissions from ETP vehicles with malfunctioning evaporative control systems (i.e., those ETP vehicles that would fail either the purge or the pressure test), EPA followed the same three-step pattern that was used for ETP vehicles with properly functioning evaporative control systems (in Section 4.1.1). That is:

1. A sample of pre-ETP vehicles was identified that could simulate these ETP vehicles.

   In Section 3.0, EPA proposed using five 1990-95 model year PFIs to represent the 1996 and newer model year vehicles that failed the pressure test (only four of which were tested over all three temperature cycles) and using eight vehicles to represent the 1996 and newer model year vehicles that failed the purge test (see Appendices E and F).

2. The means of the resting loss emissions were regressed against temperature using the three temperature points (60, 72, 82 F).

   Resting loss data on the 12 vehicles that were tested over all three temperature cycles were combined (into a single stratum) and analyzed. The resulting equation was contained in the previous draft of this report (that was released for comments).

3. After the previous draft was released (for comments), it was noted that these means also could have been modeled simply as reductions of 75 to 85 percent of the pre-ETP estimates. (Again, this is consistent with the final "bullet" on page 2, which is a re-statement of the conclusion reached in the original regulatory analysis.)

Therefore, EPA revised its approach to estimating the resting loss emissions from the malfunctioning ETP vehicles. Rather than use the new equation derived in the earlier draft version of this report, EPA chose to simply apply the previously estimated reduction factor of 75 percent to the equation for the comparable pre-ETP vehicles (from M6.EVP.001). This produces equation **(2)** below:

<u>For ETP Vehicles that Fail the Pressure Test</u>:

$$\textbf{Hourly Resting Loss (grams/hr)} = -0.02731 + [0.000703 * \textbf{Temperature (°F)}] \qquad \textbf{(2)}$$

EPA uses (in MOBILE6) equation **(2)** to estimate the hourly resting loss emissions (in grams per hour) of that portion of the fleet of ETP vehicles that fail the pressure test. Additionally, the scope (domain) of equation **(1)** was expanded to cover all ETP vehicles that pass the pressure test regardless of their performance on the purge test.

Equation **(2)** predicts that the mean hourly resting loss emissions (for the fleet of 1996 and newer model year vehicles that fail the pressure test) would be negative for all ambient temperatures below 38.8 degrees Fahrenheit. This will not present a problem, because (using the analyses from earlier versions of the MOBILE model) EPA will (in MOBILE6) assume, that for each of the hour of the day that the temperature does not exceed 40, the hourly resting loss emissions will be set to zero grams.

4.1.3 Resting Loss Emissions of "Gross Liquid Leakers"

In a parallel report (M6.EVP.001), EPA proposed that, for the pre-1996 vehicles classified as gross liquid leakers, the resting loss emissions are virtually independent of temperature, averaging 9.16 grams per hour. EPA will continue to use that assumption for the 1996 and newer vehicles that were certified to the enhanced evaporative standard. That is, the hourly resting loss emissions of all "gross liquid leakers" will be set at 9.16 grams per hour regardless of vehicle type, or model year, or ambient temperature.

4.2 <u>Diurnal Emissions</u>

The pattern of the analyses of the diurnal emissions closely paralleled the pattern that developed with the resting loss emissions. That is:

1. A samples of pre-ETP vehicles were identified that could simulate these ETP vehicles (Appendices D, E, and F).
2. The means of the diurnal emissions were regressed against a variable (VP_Product) developed in report M6.EVP.001.
3. After the previous draft was released (for comments), it was noted that these means could have been modeled simply as reductions of the pre-ETP estimates. (See the final "bullet" on page 2.)

In Section 4.1, we developed equations **(1** and **2)** that estimate the resting loss emissions for each temperature (in degrees Fahrenheit). Applying those equations to <u>each</u> hour of the full 24 hours of the RTD test, and then adding the 24 "temperature corrected" hourly resting loss emissions produces the full day's total resting loss (in grams). Subtracting that quantity from each of the RTD test scores yields the estimated (full-day) diurnal emissions in Appendices C, D, E, and F.

Two factors that significantly affect a vehicle's diurnal emissions (see M6.EVP.001 and M6.EVP.002) are:

- the Reid vapor pressure (RVP) of the test fuel and
- the temperature cycle, as represented by the combination of the cycle's midpoint temperature and temperature range.

In parallel reports (M6.EVP.001 and M6.EVP.002), we created a single parameter that incorporated both of those factors. That new parameter is based on the vapor pressure (VP) of the fuel. In those reports, we used both the RVP of the fuel and the ambient temperature to estimate the vapor pressure curve. (The RVP is the VP measured at 100 degrees Fahrenheit.) The VP was then used to create that new parameter which was used as the variable on which diurnal emissions were calculated. That new parameter is defined by the following formula, equation **(3)**.

$$\text{VP\_Product\_Term} = (\text{VPHIGH} - \text{VPLOW}) * (VP_{HIGH} + VP_{LOW}) / 2 \quad (3)$$

Where

VP_{HIGH} is the VP (in kiloPascals) associated with the day's high temperature.

VP_{LOW} is the VP (in kiloPascals) associated with the day's low temperature.

The analyses in those parallel reports modeled the diurnal emissions as functions either of that VP product term or powers of that VP product term.

4.2.1 Diurnal Emissions of Properly Functioning Vehicles

Appendix D identifies 10 pre-ETP vehicles whose RTD emissions suggests that they might be representative of ETP vehicles with properly functioning evaporative control systems (i.e., passing both the purge and pressure tests). Averaging the 45 test results on those 10 vehicles produces the following table (including both standard deviations and 90 percent confidence intervals for each of the nine values).

Table 3

Mean Diurnal Emissions of 10 Possible "ETP-Like" Vehicles
(grams / day)

Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term	Count	Mean Diurnal (grams)	Standard Deviation (grams)	90% Conf. Interval	
6.3	60 - 84	322	2	0.4740	0.0792	0.3819	0.5661
6.3	72 - 96	489	3	0.3220	0.1497	0.1798	0.4642
6.3	82 - 106	684	3	0.6487	0.2844	0.3786	0.9187
6.8	60 - 84	375	4	0.1210	0.0579	0.0734	0.1686
6.8	72 - 96	567	8	0.4398	0.1615	0.3458	0.5337
6.8	82 - 106	789	5	0.7096	0.2133	0.5527	0.8665
9.0	60 - 84	655	7	0.1727	0.0799	0.1230	0.2224
9.0	72 - 96	969	7	0.5533	0.3419	0.3407	0.7659
9.0	82 - 106	1,324	6	2.9615	3.0172	0.9353	4.9877

After initially modeling these values as a function of that VP_Product term, it was noted that they could be modeled simply as a reduction of estimated pre-ETP diurnal emissions (from report M6.EVP.001). The exact magnitude of that reduction was more difficult to determine. Comparing these nine mean diurnals with the corresponding estimates for the pre-ETP vehicles, it was noted that these means represent reductions ranging from 48 to 90 percent from the predicted pre-ETP vehicles.

Since we are uncertain how representative these 10 pre-ETP vehicles are of the actual in-use ETP vehicles, EPA decided to retain the earlier, more conservative estimate (based on engineering analyses). That is the full-day diurnal emissions of these ETP vehicles (with properly functioning evaporative control systems) will be estimated as being 50 percent reductions of the corresponding pre-ETP vehicles. This produces equation **(4)** below:

$$\text{Full-Day Diurnal (grams)} = 0.19415 + [\, 0.00252 * \text{Sqr of VP\_Product} \,/\, 1{,}000 \,] \quad (4)$$

In MOBILE6, EPA uses equation **(4)** to estimate the 24-hour diurnal emissions of all ETP vehicles with properly functioning evaporative control systems with the following two modifications:

1) Regardless of the increase in ambient temperatures, there are <u>no</u> diurnal emissions until the ambient temperature exceeds 40°F. (This assumption was used consistently for all evaporative emissions in MOBILE5.)

   For a temperature cycle in which the daily low temperature is below 40° F, EPA calculate the diurnals emissions for that day as an interrupted diurnal (see M6.EVP.002) that begins once the ambient temperature reaches 40° F.

2) The 24-hour diurnal emissions will be zero grams for any temperature cycle in which the diurnal temperature range is zero degrees Fahrenheit (i.e., a constant temperature throughout the entire day).

   For temperature cycles in which the diurnal temperature range is between zero and ten degrees Fahrenheit, the 24-hour diurnal emissions will be a linear interpolation between the predicted value for the ten-degree cycle (with the appropriate RVP) and zero grams.

4.2.1.1 Multi-Day Diurnal Emissions of Properly Functioning Vehicles

In a parallel report (M6.EVP.003, entitled "Evaluating Multiple Day Diurnal Evaporative Emissions Using RTD Tests"), EPA develops equations for estimating the RTD emissions of the second and third days of a multi-day diurnal test based on several factors, including the reciprocal of the diurnal emissions of the first day. Those analyses were based on the 270-vehicle sample (all pre-ETP vehicles) described in Section 2.0 of this report. The estimate (from that parallel report) of the ratio of the day-2 diurnal to the day-1 diurnal for fuel-injected vehicles that pass both the purge and pressure tests is given by the formula:

$$\text{Ratio} = 0.74 + [\, 47.48 - (\, 0.70 * \text{Mid-Point\_Temp} \,) + (\, 0.12 * \text{Weathered\_RVP} * \text{Mid-Point\_Temp} \,) - (\, 8.11 * \text{Weathered\_RVP} \,)\,] \,/\, \text{Full-Day\_Diurnal}$$

Applying this formula to the data in Appendix A (with Mid-Point Temperature = 84, RVP = 9.0, and full-day diurnal = 0.745) produces a ratio (of day-2 to day-1) of 9.344. That is, the predicted second day diurnal would be an unrealistically high value of 6.96 grams (far higher than <u>any</u> of the values in Appendix A). A similar problem exists in using the equations from M6.EVP.003 to estimate the third day diurnals from these vehicles. From a mathematical standpoint, this problem results from dividing by the extremely low diurnal emissions associated with this <u>single</u> stratum.

To obtain more realistic estimates of the second and third day diurnals from ETP vehicles with properly functioning evaporative control systems, EPA examined the RTD test results in Appendix A. Most (56 out of 65) of those actual ETP vehicles exhibited a decrease in RTD emissions from the first day to the second day, and the same number exhibited a decrease from the second day to the third day. (The decrease in RTD emissions was small, averaging four to ten percent.) Performing regression analyses on the 65 RTD tests in Appendix A, we obtained the following two tables. (Table 4 contains the statistics of the linear regression of the second day RTD to the first day RTD, and Table 5 contains the statistics of the linear regression of the third day to the second day.

<u>Table 4</u>

Regression of Day-2 versus Day-1 RTD Emissions

(65 Certification ETP Vehicles)

Dependent variable is: **Day_2_of_3**

No Selector

R squared = 91.0% R squared (adjusted) = 90.9%

s = 0.0905 with 65 - 2 = 63 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	5.24310	1	5.24310	640
Residual	0.516051	63	0.008191	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	-0.013504	0.0294	-0.459	0.6479
Day_1_of_3	0.924233	0.0365	25.3	≤ 0.0001

Table 5

Regression of Day-3 versus Day-2 RTD Emissions

(65 Certification ETP Vehicles)

Dependent variable is: **Day_3_of_3**
No Selector

R squared = 93.7%   R squared (adjusted) = 93.6%
s = 0.0770 with 65 - 2 = 63 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	5.57703	1	5.57703	940
Residual	0.373598	63	0.005930	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	-0.016523	0.0237	-0.698	0.4876
Day_2_of_3	0.984061	0.0321	30.7	$\leq$ 0.0001

Based on this limited analysis, EPA will estimate (in MOBILE6) the second and subsequent day of diurnal emissions to be unchanged from the first day for this stratum of ETP vehicles with properly functioning evaporative control systems.

4.2.2 Diurnal Emissions of Malfunctioning Vehicles

Appendices E and F identify eight pre-ETP vehicles failing only the purge test and five pre-ETP vehicles failing the pressure test that they might be representative of ETP vehicles with malfunctioning evaporative control systems. Averaging the test results on those vehicles produce Tables 6 and 7, respectively.

Table 6

Mean Diurnal Emissions of Eight 1990-1995 PFI Vehicles Failing ONLY the Purge Test

Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term	Count	Mean Diurnal (grams)	Standard Deviation (grams)	90% Conf. Interval	
6.3	60 - 84	322	2	0.6565	0.9284	0	1.7364
6.3	72 - 96	489	3	1.1607	1.4806	0	2.5669
6.3	82 - 106	684	3	2.5117	3.2896	0	5.6360
6.8	60 - 84	375	5	1.3934	2.3378	0	3.1133
6.8	72 - 96	567	7	2.4154	2.5391	0.8368	3.9941
6.8	82 - 106	789	7	7.5069	7.8215	2.6438	12.3699
9.0	60 - 84	655	8	3.2950	4.8373	0.4817	6.1083
9.0	72 - 96	969	8	6.3963	7.5931	1.9801	10.8124
9.0	82 - 106	1,324	5	17.6246	6.1136	13.1271	22.1221

Table 7

Mean Diurnal Emissions of Five 1990-1995 PFI Vehicles Failing the Pressure Test

Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term	Count	Mean Diurnal (grams)	Standard Deviation (grams)	90% Conf. Interval	
6.3	60 - 84	322	1	3.8810	N/A	N/A	N/A
6.3	72 - 96	489	1	11.4250	N/A	N/A	N/A
6.3	82 - 106	684	1	18.8320	N/A	N/A	N/A
6.8	60 - 84	375	4	7.7988	5.6994	3.1110	12.4865
6.8	72 - 96	567	5	7.9950	7.3946	2.5550	13.4350
6.8	82 - 106	789	4	16.6288	11.9879	6.7687	26.4888
9.0	60 - 84	655	4	10.5270	9.1762	2.9796	18.0744
9.0	72 - 96	969	4	21.0090	14.6606	8.9506	33.0674
9.0	82 - 106	1,324	4	37.3610	24.6794	17.0622	57.6598

After initially modeling these two tables of values as functions of the VP_Product term, it was noted that the equations already developed (in report M6.EVP.001) as estimates of the diurnal emissions from pre-ETP vehicles (with malfunctioning evaporative control systems) accurately model these two sets of data. Therefore, EPA is using (in MOBILE6) the following two equations from (M6.EVP.001):

<u>For ETP Vehicles that Fail ONLY the Purge Test</u>:

$$\text{Full-Day Diurnal (grams)} = 3.25800 + [\,0.00941 * \text{Sqr of VP\_Product} / 1{,}000\,] \quad (5)$$

<u>For ETP Vehicles that Fail the Pressure Test</u>:

$$\text{Full-Day Diurnal (grams)} = 0.47846 + [\,0.01497 * \text{Sqr of VP\_Product} / 1{,}000\,] \quad (6)$$

4.2.3 Diurnal Emissions of "Gross Liquid Leakers"

In a parallel report (Section 5 of report number M6.EVP.002), EPA proposed estimating the mean of the diurnal emissions for each temperature cycle of the vehicles classified as "gross liquid leakers" using equation **(7)**, below. That equation predicts diurnal emissions as a function of a single variable, the diurnal temperature range (i.e., the daily high temperature minus the daily low temperature):

<u>For ETP Vehicles That Have Gross Liquid Leaks</u>:

$$\text{Full-Day Diurnal (grams)} = 20.058 + [\,3.343 * \text{Diurnal\_Temperature\_Range}\,] \quad (7)$$

EPA will continue to use equation **(7)** to estimate the mean 24-hour diurnal emissions of all gross liquid leakers regardless of model year whenever the diurnal temperature range is at least 10 degrees Fahrenheit. The 24-hour diurnal emissions will be zero grams for any temperature cycle in which the diurnal temperature range is zero degrees Fahrenheit (i.e., a constant temperature throughout the entire day). For temperature cycles in which the diurnal temperature range is between zero and ten degrees Fahrenheit, the 24-hour diurnal emissions will be a linear interpolation of the predicted value for the ten-degree cycle (i.e., 53.49 grams) and zero grams.

5.0 DISTRIBUTION OF ETP VEHICLES

In a parallel report (M6.EVP.006, entitled "Estimating Weighting Factors for Evaporative Emissions in MOBILE6"), EPA developed estimates for the distribution of the pre-ETP (i.e., pre-1996) vehicles for the following four strata (identified in Section 3.0):

1) "gross liquid leakers," or simply GLLs (i.e., vehicles having substantial leaks of liquid gasoline as opposed to simply vapor leaks),

2) non-GLLs that pass <u>both</u> the purge and pressure tests (i.e., vehicles with properly functioning evaporative control systems),

3) non-GLLs that fail the pressure test (regardless of their performance on the purge test), and

4) non-GLLs that fail only the purge test.

At each age (where "age" equals "current year" minus "model year"), the sum of the four strata must equal 100 percent. For each of the first three of the four strata (of pre-ETP vehicles), an equation was developed that estimated the fraction of the vehicle population contained within that stratum for each "age" (where "age" equals 0, 1, 2, . . ., 24). The fourth stratum (non-ETPs failing only purge) is simply the remainder (i.e., 100 percent minus the sum of the other three strata). Two factors are expected to alter that distribution of the pre-ETP vehicles:

- the increased durability requirements of the ETP rule and
- the presence of an on-board diagnostic (OBD) system.

5.1 Effects of Changing Durability Requirements

The ETP rules require an increase in the durability of the evaporative control systems of the newer vehicles. Specifically, the ETP vehicles are required to meet the evaporative standards for ten years (100,000 miles) instead of five years (50,000 miles). EPA expects that this doubling of the durability requirement will affect the distribution of those four strata.

Until in-use data on the ETP vehicles become available, EPA will assume in MOBILE6 that the doubling of the durability requirement will result in reducing the failure rates to that of vehicles half the age. For example, the failure rates (on the purge test, pressure test, or liquid leak criterion) observed on the pre-ETP vehicles at the age of eight years would not occur on the ETP vehicles until twice that age (i.e., 16 years).

Modifying the equations (by replacing "**AGE**" with "**AGE/2**") for the pre-ETP vehicles in the parallel report (M6.EVP.006) produces the following three equations to predict the distributions (at each age) for the ETP strata:

Rate of Gross Liquid Leakers on the RTD Test for the ETP Vehicles:

$$\mathbf{GLL} = \frac{0.08902}{1 + 414.613 \cdot \exp(-0.1842 \cdot AGE)}$$

Failure Rate on Pressure Test of ETP Vehicles:

$$= \frac{0.6045}{1 + 17.733 \cdot \exp[-0.003405 \cdot (AGE^2)]} \cdot (1 - GLL)$$

Rate of Passing Both for ETP Vehicles:

$$= \left(1 - \frac{0.7200}{1 + 13.40*\exp[-0.003625*(AGE^2)]}\right) * (1 - GLL)$$

5.2 Effects of On-Board Diagnostic (OBD) Systems

The majority of the light-duty vehicles have been equipped with on-board diagnostic (OBD) systems since the early 1980’s. The latest generation of these systems (OBD II) is designed to warn the driver when a malfunctioning component is likely to cause high (exhaust or evaporative) emissions.

The factors expected to determine the effect of the presence of OBD on the evaporative emissions of the ETP vehicles are:

- the ability of OBD to identify malfunctions that result in high evaporative emissions and
- the response of the driver/owner to that warning.

The "response of the driver/owner to that warning" is most likely dependent the manufacturer’s warrantee and the presence of an Inspection / Maintenance (I/M) program. These factors are explored in detail in parallel reports (section 3.4.2 of report M6.EXH.009, entitled "Determination of CO Basic Emission Rates, OBD and I/M Effects for Tier 1 and Later LDVs and LDTs").

6.0 OTHER TYPES OF EVAPORATIVE EMISSIONS

Two other types of evaporative emissions (in addition to the resting loss and diurnal emissions) are affected by the ETP requirements. These are the hot soak emissions and the running loss emissions.

Hot Soak emissions are the evaporative emissions produced after the vehicle has been driven. These emissions can also be thought of as "trip end" emissions. They result from the fact that the vehicle, engine, fuel delivery system including tank, are all well above ambient temperatures after all but the very shortest trips. In MOBILE6, EPA assumes the following effects of the ETP requirements on <u>hot soak</u> emissions:

- no effect on vehicles classified as "gross liquid leakers,"
- a reduction (compared to the pre-ETP vehicles) of 50 percent on LDGVs with properly functioning evaporative control systems (i.e., vehicles that pass <u>both</u> the purge and pressure tests), and
- a smaller reduction on vehicles with malfunctioning evaporative control systems (i.e., vehicles that fail either the purge or pressure tests).

This "smaller reduction" on vehicles with malfunctioning evaporative control systems depends upon the ambient temperature. The reduction is 30 percent for ambient temperatures of at least 95 degrees Fahrenheit. The reduction decreases (linearly) to zero at temperatures of 65 degrees Fahrenheit or colder. Therefore, the reduction (as a percentage) is given by the following formula:

Reduction = Temperature - 65, where

the "**Reduction**" is "capped" by zero and 30 (percents).

Similar to the hot soak emissions, the running loss evaporative emissions, which are produced during periods of vehicle operation (that is, driving or idling), are also affected by the ETP requirements:

- no effect on running loss emissions for vehicles classified as "gross liquid leakers,"
- a reduction (compared to the pre-ETP vehicles) of 80 percent on LDGVs with properly functioning evaporative control systems (i.e., vehicles that pass both the purge and pressure tests), and
- a smaller reduction on vehicles with malfunctioning evaporative control systems (i.e., vehicles that fail either the purge or pressure tests).

This "smaller reduction" on running loss emissions for vehicles with malfunctioning evaporative control is identical to the corresponding reduction in hot soak emissions for these same vehicles.

7.0 EVAPORATIVE EMISSIONS OF HEAVY-DUTY VEHICLES

EPA did not conduct RTD testing of the heavy-duty gasoline-fueled vehicles (HDGVs). In MOBILE6, EPA estimates the evaporative emissions of these untested vehicle types proportional to their emission standards. (This is the same approach used in earlier versions of MOBILE.)

For the HDGVs from 8,501 pounds gross vehicle weight rating (GVWR) up through 14,000 pounds (i.e., HDGV classes IIb and 3), the ETP standard for the combined RTD and hot soak tests is 3.0 grams (as compared to the 2.0 grams for the LDGTs). Therefore, in MOBILE6, this ratio (i.e., 1.5 = 3.0 / 2.0) is applied to the applicable LDGT evaporative emissions (i.e., hot soak emissions, resting loss emissions, and diurnal emissions) to estimate the corresponding evaporative emissions for these HDGVs that are not GLLs. (We are assuming that the average emissions of the GLLs are not affected by the ETP requirements.)

Similarly, for the HDGVs over 14,000 pounds (i.e., HDGV classes 4 through 8b and busses), since the combined RTD and hot soak tests is 4.0 grams, a multiplier of 2.0 (i.e., 2.0 = 4.0 / 2.0) is applied to the applicable LDGT evaporative emissions from non-GLLs.

8.0 EFFECTS OF THE ORVR RULES

"Refueling Emissions" are the evaporative emissions produced while the vehicle is being refueled and gasoline vapors are forced out as liquid gasoline takes their place. The refueling emissions are basically the average displaced vapor (5.26 grams of HC) per gallon of dispensed fuel, plus a small amount for spillage (0.31 grams). These refueling emissions can be reduced with the use of Onboard Refueling Vapor Recovery (ORVR) systems.

The phase-in rates (percents of vehicles) required by the regulations are given in the following table (Table 8). (The ORVR regulations for light-duty cars and trucks were issued April 6, 1994 (**59 FR 16262**). The ORVR regulations for HD Class 2b vehicles were issued October 6, 2000 (**65 FR 59924**) as part of the "2004 Heavy-Duty" rule.)

Table 8

Phase-In of ORVR Systems
(Required Percentages by Vehicle Class and Model Year)

Model Year	LDGVs	LDGTs GVWR Up To 6,000	LDGTs 6,001 Up To 8,500	HDGTs 8,501 Up To 10,000
1997	0%	0%	0%	0%
1998	40%	0%	0%	0%
1999	80%	0%	0%	0%
2000	100%	0%	0%	0%
2001	100%	40%	0%	0%
2002	100%	80%	0%	0%
2003	100%	100%	0%	0%
2004	100%	100%	40%	0%
2005	100%	100%	80%	80%
2006	100%	100%	100%	100%

For light-duty cars and trucks, the ORVR effectiveness was assumed (in MOBILE5) to reduce the portion of refueling emissions that does not include spillage by 98 percent, and to reduce the spillage by 50 percent. We will continue that assumption for

MOBILE6. New for MOBILE6, is the extension of that assumption to the HD Class 2b vehicles, phasing-in with the 2005 model year.

Table 8 indicates that the phase-in for the HD Class 2b vehicles assumes zero percent for the 2004 model year. Actually, the regulations permit, for the 2004 model year, an optional phase-in of up to 40 percent. However, since the 2004 phase-in is only "optional," we will assume a value of zero until actual vehicle counts are available.

9.0 EFFECTS OF THE TIER-2 RULE

Beginning with the 2004 model year, manufacturers will be required to certify at least twenty-five percent of their gasoline-fueled passenger cars (LDVs) to the new Tier-2 standards; that percentage of Tier-2 vehicles will increase to one hundred percent within a few additional years. A similar phase-in will be required of the light-duty gasoline-fueled trucks (LDGTs) and the heavy-duty gasoline-fueled trucks (HDGTs) in class 2b (6,001 through 8,500 pounds GVWR). The 2007 Heavy-Duty rule extended this to all of the other heavy-duty and bus classes. The phase-in rates (percents of vehicles) required by the regulations are given in the following table (Table 9).

Table 9

Phase-In of Tier-2 Vehicles
(Required Percentages by Vehicle Class and Model Year)

Model Year	LDGVs	LDGTs GVWR Up To 6,000	LDGTs 6,001 Up To 8,500	ALL HDGTs GVWR Over 8,500
2003	0%	0%	0%	0%
2004	25%	25%	0%	0%
2005	50%	50%	0%	0%
2006	75%	75%	0%	0%
2007	100%	100%	0%	0%
2008	100%	100%	50%	50%
2009	100%	100%	100%	100%

Concurrent with the phase-in of the new (more stringent) Tier-2 evaporative requirements will be the phase-in by California of its even more stringent LEV II evaporative standards. The evaporative standards for both the Tier-2 and LEV II programs are given in Table 10 (on the following page).

Table 10

Evaporative Standards Under Tier-2 and LEV II
(grams/test over 3-day diurnal + hot soak)

Vehicle Class	Current (ETP)	Tier 2	LEV II
LDV	2.0	0.95	0.5
LDT-1		0.95	0.65
LDT-2		0.95	0.65
LDT-3 & 4		1.2	0.95

As explained in a parallel report (report number M6.EXH.007, entitled "Accounting for the Tier 2 and Heavy-Duty 2005/2007 Requirements in MOBILE6"), the vehicle manufacturers have stated that rather than producing separate systems for California and the rest of the country, they will produce single federal systems that also comply with the more stringent California standards. Therefore, in MOBILE6, EPA assumes the evaporative emissions will be based on the LEV II standards.

Thus, in MOBILE6, EPA assumes the following effects of the Tier-2 requirements on diurnal, resting loss, and hot soak emissions:

- no effect on vehicles classified as "gross liquid leakers,"
- no effect on vehicles with malfunctioning evaporative control systems (i.e., vehicles that fail either the purge or pressure tests),
- a reduction (compared to ETP vehicles) of 75 percent on all LDVs with properly functioning evaporative control systems (i.e., vehicles that pass <u>both</u> the purge and pressure tests),
- a reduction (compared to ETP vehicles) of 67.5 percent on LDGTs up to 6,000 pounds (GVWR) (i.e., LDT-1 and LDT-2) with properly functioning evaporative control systems (i.e., vehicles that pass <u>both</u> the purge and pressure tests),
- a reduction (compared to ETP vehicles) of 52.5 percent on all LDGTs with GVWR from 6,001 to 8,500 pounds (i.e., LDT-3 and LDT-4) and with properly functioning evaporative control systems (i.e., vehicles that pass <u>both</u> the purge and pressure tests),
- for HDGTs with GVWR up to 14,000 pounds and with properly functioning evaporative control systems (i.e., vehicles that pass both the purge and pressure tests), emissions will be 1.474 times the corresponding emissions of the Tier-2 LDGTs with GVWR from 6,001 to

8,500 (i.e., proportional to the certification standards), and

- for HDGTs with GVWR over 14,000 pounds and with properly functioning evaporative control systems (i.e., vehicles that pass both the purge and pressure tests), emissions will be 2.000 times the corresponding emissions of the Tier-2 LDGTs with GVWR from 6,001 to 8,500 (i.e., proportional to the certification standards).

10.0 SUMMARY

For most of the 1996 and newer model year vehicles that were certified to the enhanced evaporative testing procedure (ETP), EPA will model (in MOBILE6) the resting loss and diurnal emissions similar to what was done in the previous version of the MOBILE model (i.e., MOBILE5). That is:

- For those ETP vehicles with properly functioning evaporative control systems (i.e., vehicles passing both the purge test and the pressure test), full-day diurnal emissions will be reduced by 50 percent compared to the corresponding pre-ETP vehicles.

- For those ETP vehicles with malfunctioning evaporative control systems (i.e., vehicles failing either the purge test or the pressure test), there will be no reduction (zero percent) of full-day diurnal emissions compared to the corresponding pre-ETP vehicles.

- For all ETP vehicles, resting loss emissions will be reduced by 75 percent compared to the corresponding pre-ETP vehicles.

New to MOBILE6 are:

- The emissions of "Gross Liquid Leakers" will be unaffected by the ETP requirements.

- The assumption of increased durability will reduce the predicted number of higher emitting vehicles.

- The presence of an OBD II system will reduce the number of higher emitting vehicles (depending upon the manufacturer’s warrantee and I/M programs).

- The Tier-2 requirements will reduce the emissions of gasoline-fueled cars and trucks (up to 14,000 pounds GVWR) that have properly functioning evaporative control systems.

Appendix A

Certification Tests on 65 ETP Vehicles

30 Vehicles for California Certification

Source	Make	----- RTD Test ---- (grams per day) Day 1	Day 2	Day 3	Hot Soak (g/hr)
CERT-ARB	FORD	0.824	0.765	0.711	0.154
CERT-ARB	FORD	0.415	0.385	0.355	0.130
CERT-ARB	FORD	0.680	0.420	0.420	0.160
CERT-ARB	FORD	0.415	0.430	0.420	0.095
CERT-ARB	FORD	1.675	1.710	1.765	0.140
CERT-ARB	GM	1.100	1.105	1.225	0.130
CERT-ARB	GM	1.356	1.147	1.064	0.220
CERT-ARB	GM	1.150	1.040	0.847	0.087
CERT-ARB	GM	0.757	0.645	0.620	0.131
CERT-ARB	MITSUB	0.742	0.545	0.544	0.207
CERT-ARB	CHRYS	0.810	0.785	0.806	0.137
CERT-ARB	CHRYS	0.719	0.688	0.680	0.070
CERT-ARB	TOYOTA	0.680	0.662	0.666	0.100
CERT-ARB	TOYOTA	0.530	0.430	0.420	0.060
CERT-ARB	TOYOTA	0.520	0.450	0.430	0.070
CERT-ARB	TOYOTA	0.610	0.500	0.480	0.150
CERT-ARB	HONDA	0.360	0.320	0.300	0.090
CERT-ARB	HONDA	0.460	0.370	0.240	0.110
CERT-ARB	HONDA	0.410	0.350	0.350	0.121
CERT-ARB	HONDA	0.490	0.420	0.400	0.160
CERT-ARB	MAZDA	0.625	0.740	0.778	0.120
CERT-ARB	MAZDA	0.635	0.584	0.597	0.100
CERT-ARB	MAZDA	0.548	0.508	0.499	0.250
CERT-ARB	MAZDA	0.500	0.530	0.420	0.120
CERT-ARB	NISSAN	0.518	0.463	0.467	0.130
CERT-ARB	NISSAN	0.549	0.460	0.483	0.072
CERT-ARB	VOLKS	0.734	0.625	0.607	0.177
CERT-ARB	VOLKS	0.960	0.870	0.830	0.280
CERT-ARB	VOLKS	1.250	1.040	0.978	0.250
CERT-ARB	ISUZU	1.235	1.115	1.046	0.355

Appendix A (Continued)

Certification Tests on 65 ETP Vehicles

36 Vehicles for EPA Certification

		----- RTD Test ---- (grams per day)			Hot Soak
Source	**Make**	**Day 1**	**Day 2**	**Day 3**	**(g/hr)**
CERT-EPA	FORD	1.039	0.860	0.791	0.177
CERT-EPA	FORD	1.060	0.828	0.719	0.190
CERT-EPA	FORD	1.210	1.172	1.139	**N.A.**
CERT-EPA	FORD	0.832	1.127	1.230	0.134
CERT-EPA	FORD	1.135	0.984	0.878	0.211
CERT-EPA	GM	0.589	0.485	0.485	0.168
CERT-EPA	GM	**N.A.**	**N.A.**	**N.A.**	0.172
CERT-EPA	GM	0.764	0.644	0.666	0.266
CERT-EPA	GM	0.669	0.560	0.521	0.208
CERT-EPA	GM	0.440	0.300	0.330	0.070
CERT-EPA	HONDA	0.610	0.559	0.541	0.070
CERT-EPA	HONDA	0.817	0.754	0.796	0.100
CERT-EPA	HONDA	0.813	0.636	0.353	0.460
CERT-EPA	MAZDA	0.588	0.703	0.580	0.080
CERT-EPA	MAZDA	0.567	0.500	0.528	0.130
CERT-EPA	MAZDA	0.600	0.530	0.510	0.310
CERT-EPA	MAZDA	0.490	0.500	0.200	0.120
CERT-EPA	TOYOTA	0.600	0.530	0.510	0.310
CERT-EPA	TOYOTA	0.390	0.320	0.310	0.030
CERT-EPA	TOYOTA	0.350	0.340	0.370	0.030
CERT-EPA	TOYOTA	0.340	0.260	0.250	0.070
CERT-EPA	NISSAN	0.600	0.430	0.410	0.110
CERT-EPA	NISSAN	0.491	0.456	0.436	0.057
CERT-EPA	NISSAN	0.594	0.572	0.553	0.096
CERT-EPA	NISSAN	0.463	0.417	0.425	0.107
CERT-EPA	VOLKS	0.402	0.396	0.424	0.041
CERT-EPA	VOLKS	0.626	0.533	0.534	0.109
CERT-EPA	VOLKS	0.670	0.630	0.610	0.190
CERT-EPA	VOLKS	0.960	0.870	0.830	0.280
CERT-EPA	CHRYSLER	1.100	1.245	1.275	0.355
CERT-EPA	CHRYSLER	1.310	1.230	1.080	0.230
CERT-EPA	CHRYSLER	1.469	1.181	1.004	0.140
CERT-EPA	CHRYSLER	0.741	0.686	0.825	0.170
CERT-EPA	ISUZU	0.847	0.779	0.749	0.448
CERT-EPA	ISUZU	0.594	0.538	0.531	0.187
CERT-EPA	ISUZU	1.375	1.200	1.243	**N.A.**

Appendix B

CAP-2000 Data on Six 1996 Model Year Mercedes ETP Vehicles

Model	Test Date	Odometer (miles)	Total HC Diurnal + Hot Soak (grams*)	Hot Soak (grams*)	2-Day Diurnal (grams*)
S420	11/26/97	46,846	0.4687	0.0807	0.388
S500	12/12/97	31,447	0.4336	0.0736	0.360
S500	01/09/98	38,099	0.4229	0.0839	0.339
S420	01/20/98	29,997	0.7171	0.1101	0.607
S420	02/06/98	26,606	0.4317	0.0867	0.345
S420	02/27/98	42,870	0.6935	0.1255	0.568
				Mean:	0.4345

* The units "grams" are somewhat inconsistent.

"Grams" on the Hot Soak test refers to grams per test. Since each test is one hour in duration, this is equivalent to grams per hour.

"Grams" on the Diurnal (RTD) test refers to grams per day.

"Grams" in the "Total" column are the sum of the grams per hour on the hot soak and the grams per day on the diurnal tests. This "mixed" unit is the basis of the standard used for the ETP certification.

Appendix C

Twenty-Five 1990-1995 Model Year Vehicles Passing Both the Purge and Pressure Tests

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
4912	6.8	72 - 96	567	0.980	0.012	0.428	0.552
	6.8	82 - 106	789	5.120	0.102	2.588	2.532
	9.0	60 - 84	655	1.930	-0.005	0.020	1.910
	9.0	72 - 96	969	3.350	0.045	1.220	2.130
4923	6.8	72 - 96	567	0.670	0.000	0.140	0.530
	6.8	82 - 106	789	4.480	0.048	1.292	3.188
	9.0	60 - 84	655	1.710	0.018	0.572	1.138
	9.0	72 - 96	969	2.550	0.032	0.908	1.642
4928	6.8	72 - 96	567	4.830	0.065	1.700	3.130
	6.8	82 - 106	789	8.230	0.142	3.548	4.682
	9.0	60 - 84	655	4.170	0.045	1.220	2.950
	9.0	72 - 96	969	4.370	0.058	1.532	2.838
4932	6.8	72 - 96	567	1.700	0.017	0.548	1.152
	6.8	82 - 106	789	2.850	0.037	1.028	1.822
	9.0	60 - 84	655	1.490	0.023	0.692	0.798
	9.0	72 - 96	969	2.080	0.017	0.548	1.532
5032	6.8	60 - 84	375	0.374	0.004	0.236	0.138
	6.8	72 - 96	567	0.772	0.006	0.284	0.488
	6.8	82 - 106	789	1.231	0.012	0.428	0.803
	9.0	60 - 84	655	0.473	0.005	0.260	0.213
	9.0	72 - 96	969	0.741	0.008	0.332	0.409
	9.0	82 - 106	1,324	2.433	0.018	0.572	1.861
5038	6.8	72 - 96	567	0.615	0.005	0.260	0.355
	6.8	82 - 106	789	1.011	0.007	0.308	0.703
	9.0	60 - 84	655	0.441	0.002	0.188	0.253
	9.0	72 - 96	969	1.302	0.004	0.236	1.066
	9.0	82 - 106	1,324	4.366	0.006	0.284	4.082

* "Hourly Resting Loss" emissions are calculated at the lowest temperature of each cycle.

Appendix C (Continued)

Twenty-Five 1990-1995 Model Year Vehicles Passing Both the Purge and Pressure Tests

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
5046	6.8	60 - 84	375	0.439	0.011	0.404	0.035
	6.8	72 - 96	567	0.565	0.007	0.308	0.257
	6.8	82 - 106	789	1.498	0.020	0.620	0.878
	9.0	60 - 84	655	0.360	0.004	0.236	0.124
	9.0	72 - 96	969	0.971	0.013	0.452	0.519
	9.0	82 - 106	1,324	9.716	0.041	1.124	8.592
5047	9.0	60 - 84	655	0.366	0.005	0.260	0.106
	9.0	72 - 96	969	0.653	0.012	0.428	0.225
	9.0	82 - 106	1,324	0.906	0.015	0.500	0.406
5052	6.8	60 - 84	375	3.502	0.032	0.908	2.594
	6.8	72 - 96	567	4.273	0.071	1.844	2.429
	6.8	82 - 106	789	8.937	0.114	2.876	6.061
	9.0	60 - 84	655	2.966	0.039	1.076	1.890
	9.0	72 - 96	969	5.853	0.106	2.684	3.169
	9.0	82 - 106	1,324	11.820	0.205	5.060	6.760
5066	6.3	60 - 84	322	0.390	-0.007	-0.028	0.418
	6.3	72 - 96	489	0.351	0.001	0.164	0.187
	6.3	82 - 106	684	0.605	0.006	0.284	0.321
	6.8	60 - 84	375	0.295	0.000	0.140	0.155
	6.8	72 - 96	567	0.397	0.003	0.212	0.185
	6.8	82 - 106	789	0.581	0.004	0.236	0.345
	9.0	60 - 84	655	0.281	-0.001	0.116	0.165
	9.0	72 - 96	969	0.626	0.007	0.308	0.318
	9.0	82 - 106	1,324	1.936	0.011	0.404	1.532
5068	6.3	60 - 84	322	0.814	0.006	0.284	0.530
	6.3	72 - 96	489	0.580	0.006	0.284	0.296
	6.3	82 - 106	684	1.150	0.009	0.356	0.794
	6.8	60 - 84	375	0.368	0.003	0.212	0.156
	6.8	72 - 96	567	0.839	0.009	0.356	0.483
	6.8	82 - 106	789	1.391	0.018	0.572	0.819
	9.0	60 - 84	655	0.638	0.009	0.356	0.282
	9.0	72 - 96	969	1.385	0.010	0.380	1.005
	9.0	82 - 106	1,324	2.132	0.029	0.836	1.296

Appendix C (Continued)

Twenty-Five 1990-1995 Model Year Vehicles Passing Both the Purge and Pressure Tests

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
5081	6.3	72 - 96	489	0.647	0.001	0.164	0.483
	6.3	82 - 106	684	1.187	0.009	0.356	0.831
	9.0	60 - 84	655	0.326	0.005	0.260	0.066
	9.0	72 - 96	969	0.639	0.007	0.308	0.331
9009	6.8	72 - 96	567	35.565	0.095	2.420	33.145
9026	6.8	72 - 96	567	1.755	0.031	0.884	0.871
9028	6.8	72 - 96	567	16.984	0.024	0.716	16.268
9033	6.8	72 - 96	567	0.879	0.003	0.212	0.667
9038	6.8	72 - 96	567	5.818	0.106	2.684	3.134
9040	6.8	72 - 96	567	0.810	0.006	0.284	0.526
9048	6.8	72 - 96	567	9.443	0.228	5.612	3.831
9056	6.8	72 - 96	567	3.095	0.046	1.244	1.851
9059	6.8	72 - 96	567	1.009	0.013	0.452	0.557
9088	6.8	72 - 96	567	2.750	0.023	0.692	2.058
9135	6.8	72 - 96	567	1.591	0.012	0.428	1.163
9141	6.8	72 - 96	567	10.328	0.209	5.156	5.172
9143	6.8	72 - 96	567	7.904	0.070	1.820	6.084

Appendix D

Ten Possible "ETP-Like" 1990-1995 Model Year Vehicles Passing Both the Purge and Pressure Tests Tested Over Multiple Cycles (Subset of Appendix C)

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
5032	6.8	60 - 84	375	0.374	0.004	0.236	0.138
	6.8	72 - 96	567	0.772	0.006	0.284	0.488
	6.8	82 - 106	789	1.231	0.012	0.428	0.803
	9.0	60 - 84	655	0.473	0.005	0.260	0.213
	9.0	72 - 96	969	0.741	0.008	0.332	0.409
	9.0	82 - 106	1,324	2.433	0.018	0.572	1.861
5038	6.8	72 - 96	567	0.615	0.005	0.26	0.355
	6.8	82 - 106	789	1.011	0.007	0.308	0.703
	9.0	60 - 84	655	0.441	0.002	0.188	0.253
	9.0	72 - 96	969	1.302	0.004	0.236	1.066
	9.0	82 - 106	1,324	4.366	0.006	0.284	4.082
5046	6.8	60 - 84	375	0.439	0.011	0.404	0.035
	6.8	72 - 96	567	0.565	0.007	0.308	0.257
	6.8	82 - 106	789	1.498	0.020	0.620	0.878
	9.0	60 - 84	655	0.360	0.004	0.236	0.124
	9.0	72 - 96	969	0.971	0.013	0.452	0.519
	9.0	82 - 106	1,324	9.716	0.041	1.124	8.592
5047	9.0	60 - 84	655	0.366	0.005	0.260	0.106
	9.0	72 - 96	969	0.653	0.012	0.428	0.225
	9.0	82 - 106	1,324	0.906	0.015	0.500	0.406

* "Hourly Resting Loss" emissions are calculated at the lowest temperature of each cycle.

Appendix D (Continued)

Ten Possible "ETP-Like" 1990-1995 Model Year Vehicles Passing Both the Purge and Pressure Tests Tested Over Multiple Cycles (Subset of Appendix C)

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
5066	6.3	60 - 84	322	0.390	-0.007	-0.028	0.418
	6.3	72 - 96	489	0.351	0.001	0.164	0.187
	6.3	82 - 106	684	0.605	0.006	0.284	0.321
	6.8	60 - 84	375	0.295	0.000	0.140	0.155
	6.8	72 - 96	567	0.397	0.003	0.212	0.185
	6.8	82 - 106	789	0.581	0.004	0.236	0.345
	9.0	60 - 84	655	0.281	-0.001	0.116	0.165
	9.0	72 - 96	969	0.626	0.007	0.308	0.318
	9.0	82 - 106	1,324	1.936	0.011	0.404	1.532
5068	6.3	60 - 84	322	0.814	0.006	0.284	0.530
	6.3	72 - 96	489	0.580	0.006	0.284	0.296
	6.3	82 - 106	684	1.150	0.009	0.356	0.794
	6.8	60 - 84	375	0.368	0.003	0.212	0.156
	6.8	72 - 96	567	0.839	0.009	0.356	0.483
	6.8	82 - 106	789	1.391	0.018	0.572	0.819
	9.0	60 - 84	655	0.638	0.009	0.356	0.282
	9.0	72 - 96	969	1.385	0.010	0.380	1.005
	9.0	82 - 106	1,324	2.132	0.029	0.836	1.296
5081	6.3	72 - 96	489	0.647	0.001	0.164	0.483
	6.3	82 - 106	684	1.187	0.009	0.356	0.831
	9.0	60 - 84	655	0.326	0.005	0.260	0.066
	9.0	72 - 96	969	0.639	0.007	0.308	0.331
9033	6.8	72 - 96	567	0.879	0.003	0.212	0.667
9040	6.8	72 - 96	567	0.810	0.006	0.284	0.526
9059	6.8	72 - 96	567	1.009	0.013	0.452	0.557

* "Hourly Resting Loss" emissions are calculated at the lowest temperature of each cycle.

Appendix E

Eight 1990-1995 Model Year PFI Vehicles Failing (Only) the Purge Test

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
4925	6.8	72 - 96	567	4.170	0.063	1.949	2.221
	6.8	82 - 106	789	4.450	0.080	2.357	2.093
	9.0	60 - 84	655	2.170	0.035	1.277	0.893
	9.0	72 - 96	969	3.830	0.058	1.829	2.001
4933	6.8	72 - 96	567	10.750	0.145	3.917	6.833
	6.8	82 - 106	789	18.670	0.352	8.885	9.785
	9.0	60 - 84	655	7.170	0.137	3.725	3.445
	9.0	72 - 96	969	12.120	0.228	5.909	6.211
5004	6.8	60 - 84	375	0.989	0.003	0.509	0.480
	6.8	72 - 96	567	1.673	0.023	0.989	0.684
	6.8	82 - 106	789	2.924	0.031	1.181	1.743
	9.0	60 - 84	655	1.025	0.015	0.797	0.228
	9.0	72 - 96	969	5.440	0.018	0.869	4.571
	9.0	82 - 106	1,324	20.391	0.047	1.565	18.826
5035	6.8	60 - 84	375	5.593	-0.016	0.053	5.540
	6.8	72 - 96	567	5.869	0.016	0.821	5.048
	6.8	82 - 106	789	22.973	-0.033	-0.355	23.328
	9.0	60 - 84	655	14.493	0.015	0.797	13.696
	9.0	72 - 96	969	24.068	0.032	1.205	22.863
	9.0	82 - 106	1,324	24.872	0.040	1.397	23.475
5040	6.8	60 - 84	375	0.667	0.003	0.509	0.158
	6.8	72 - 96	567	1.143	0.010	0.677	0.466
	6.8	82 - 106	789	6.961	-0.013	0.125	6.836
	9.0	60 - 84	655	1.065	-0.003	0.365	0.700
	9.0	72 - 96	969	2.930	0.012	0.725	2.205
	9.0	82 - 106	1,324	20.658	-0.008	0.245	20.413

Appendix E (Continued)

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
5069	6.3	60 - 84	322	1.774	0.001	0.461	1.313
	6.3	72 - 96	489	3.593	0.012	0.725	2.868
	6.3	82 - 106	684	6.810	0.003	0.509	6.301
	6.8	60 - 84	375	1.322	0.004	0.533	0.789
	6.8	72 - 96	567	1.953	0.011	0.701	1.252
	6.8	82 - 106	789	9.565	0.039	1.373	8.192
	9.0	60 - 84	655	7.082	-0.017	0.029	7.053
	9.0	72 - 96	969	12.372	0.007	0.605	11.767
	9.0	82 - 106	1,324	20.430	0.080	2.357	18.073
5070	6.3	60 - 84	322	0.351	0.002	0.485	0.000
	6.3	72 - 96	489	0.690	0.001	0.461	0.229
	6.3	82 - 106	684	1.209	0.016	0.821	0.388
	6.8	60 - 84	375	0.375	0.002	0.485	0.000
	6.8	72 - 96	567	0.745	-0.004	0.341	0.404
	6.8	82 - 106	789	1.176	0.007	0.605	0.571
	9.0	60 - 84	655	0.416	0.003	0.509	0.000
	9.0	72 - 96	969	1.381	0.019	0.893	0.488
	9.0	82 - 106	1,324	9.141	0.057	1.805	7.336
5087	6.3	72 - 96	489	1.830	0.042	1.445	0.385
	6.3	82 - 106	684	2.435	0.048	1.589	0.846
	9.0	60 - 84	655	1.478	0.029	1.133	0.345
	9.0	72 - 96	969	2.533	0.043	1.469	1.064

Appendix F

Five 1990-1995 Model Year Vehicles
Failing the Pressure Test

Vehicle No.	Fuel RVP (psi)	Temp Cycle (°F)	VP Product Term (kPa^2)	RTD (gr/day)	Resting Loss (gr/hour)*	Daily Rst Loss (gr/day)	Diurnal (gr/day)
4937	6.8	72 - 96	567	3.330	0.028	1.109	2.221
5008	6.8	60 - 84	375	12.853	-0.018	0.005	12.848
	6.8	72 - 96	567	17.632	0.013	0.749	16.883
	6.8	82 - 106	789	29.663	0.054	1.733	27.930
	9.0	60 - 84	655	19.811	-0.002	0.389	19.422
	9.0	72 - 96	969	35.202	0.038	1.349	33.853
	9.0	82 - 106	1,324	57.174	0.014	0.773	56.401
5021	6.8	60 - 84	375	7.789	0.004	0.533	7.256
	6.8	72 - 96	567	15.477	0.029	1.133	14.344
	6.8	82 - 106	789	23.810	0.065	1.997	21.813
	9.0	60 - 84	655	17.246	-0.003	0.365	16.881
	9.0	72 - 96	969	24.840	0.038	1.349	23.491
	9.0	82 - 106	1,324	41.963	-0.034	-0.379	42.342
5044	6.8	60 - 84	375	0.286	0.004	0.533	0.000
	6.8	72 - 96	567	0.523	0.011	0.701	0.000
	6.8	82 - 106	789	0.706	0.014	0.773	0.000
	9.0	60 - 84	655	0.467	0.011	0.701	0.000
	9.0	72 - 96	969	0.494	0.007	0.605	0.000
	9.0	82 - 106	1,324	1.914	0.005	0.557	1.357
5067	6.3	60 - 84	322	5.206	0.037	1.325	3.881
	6.3	72 - 96	489	13.206	0.056	1.781	11.425
	6.3	82 - 106	684	21.981	0.113	3.149	18.832
	6.8	60 - 84	375	12.128	0.025	1.037	11.091
	6.8	72 - 96	567	8.644	0.070	2.117	6.527
	6.8	82 - 106	789	18.697	0.062	1.925	16.772
	9.0	60 - 84	655	7.106	0.036	1.301	5.805
	9.0	72 - 96	969	29.697	0.107	3.005	26.692
	9.0	82 - 106	1,324	50.741	0.040	1.397	49.344

Appendix G

Response to Peer Review Comments from H. T. McAdams

This report was formally peer reviewed by two peer reviewers (H. T. McAdams and Sandeep Kishan). In this appendix, comments from H. T. McAdams are reproduced in plain text, and EPA's responses to those comments are interspersed in indented italics. Comments from the other peer reviewer appear in the following appendix (Appendix H).

> *It is important to note that this final version of the report has changed substantially from the draft version that Professor McAdams reviewed. In that earlier version, the goal was to develop equations that would predict the diurnal and resting loss emissions of these ETP vehicles. In the interim between these versions of this report, we realized that the predicted results (from that draft) were comparable to the MOBILE5 predictions. Therefore, in this final version, our goal changed and became the testing and validation of those MOBILE5 predictions.*
>
> *This change of direction resulted in many of Professor McAdams' comments no longer being applicable. However, all of his comments were considered, and those that were still applicable were incorporated.*

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Modeling Diurnal and Resting Loss Emissions from Vehicles Certified to the Enhanced Evaporative Standards

Report Number M6.EVP.005

By

Larry C. Landman
Assessment and Modeling Division
U.S. EPA Office of Mobile Sources

Review and Comments By H. T. McAdams

1.0 REPORT CLARITY

Reporting the results of this study presents more than the usual challenge to the report writer. It is necessary to make a great many statements that are highly conditional, and this fact leads to sentences that sometimes are lengthy and complicated. For example, consider the following excerpt:

> EPA believes that the RTD emissions from malfunctioning enhanced evaporative control vehicles (i.e., vehicles that developed problems with their evaporative control systems) will be similar to the RTD emissions from the 1990 to 1995 model year vehicles that also develop problems with their evaporative control systems. That is, those 1996 and newer model year vehicles that had failed either EPA's purge or pressure tests are expected to have evaporative emissions similar to those 1990 to 1995 model year PFI vehicles that also failed the same test.

It is evident that the author is doing his best to keep the record straight, something not easy to do when making a statement with so many qualifiers. The problem is aggravated by the necessary wordiness of such designations as "emissions from malfunctioning enhanced evaporative control vehicles" and "emissions from the 1990 to 1995 model year vehicles that also develop problems with their evaporative control systems." The added "That is ..." phrases, intended to clinch the matter, tend only to further confuse. It might be useful to insert a simple "word table" or Venn diagram to show explicitly how the various vehicle classes are related and then to find a simple but descriptive name for each category. An example pertaining to the vapor pressure product term will be found later in this review.

The above comments are based on several years experience as technical writer and editor for Cornell Aeronautical Laboratory, now Calspan Corporation, Buffalo, NY. Though stylistic and grammatical editing are not considered to be within the scope of this review, it is believed that the report could benefit from further attention to these concerns.

2.0 OVERALL METHODOLOGY

Every scientific discipline has its own investigative and statistical parochialism. Some of the "soft sciences," like psychology and sociology, tend to thrive on correlation analysis and nonparametric statistics. The engineering sciences, on the other hand, find statistical approaches like regression analysis and formal tests of significance more to their liking. Neither scientific group can be faulted for their choice, but both would gain from cross fertilization of ideas and procedures.

The methodology employed in this report is generally consistent with the methodology followed by EPA in developing their Complex Model for Reformulated Gasoline (RFG). Heavy emphasis was put on regression analysis and the strict application of statistical tests of significance. From participation in that effort, this reviewer learned much that is applicable to Landman's study of evaporative emissions. This includes visualizing the nature of the curves, surfaces or hypersurfaces represented by the model, evaluating confidence bounds for the regression function, and estimating the relative importance of terms in the equation.

Perhaps one of the most neglected aspects of statistical analysis is the subject of the power of a test of significance. Often failing to reject a null hypothesis amounts to saying that, under the prevailing circumstances, the test simply did not have sufficient power to do so. Either the sample size was not adequate, or the data had too much dispersion, or the significance level was set too high to be appropriate for the situation at hand. More emphasis needs to be put on the reasons for using certain significance tests and on whether a given significance level, such as the commonly used 0.05, is appropriate for the present application.

This report is subject to many of the above complaints. Nevertheless, it meets essentially all criteria for a valid scientific study according to present views and standards. The plea here is that statistical principles should be applied thoughtfully rather than automatically and that there may be value in sometimes breaking from the crowd. In what follows, specific examples taken from the report will be used to illustrate some of the above contentions.

3.0 APPROPRIATENESS OF DATASETS SELECTED

The datasets available for modeling diurnal and resting loss emissions are far from ideal. As pointed out above, precision limits for estimating these emissions rest heavily on the amount and quality of the data. By quality is meant data that is not subject to bias and is not so "noisy" that it precludes all but the most evident conclusions. If the data is so bad that it leaves us with little that we did not already know, then it clearly contributes little information.

There is probably no perfect set of data. However, application of the principles of sampling and experiment design can do much to move us toward that goal. In particular, they can help us estimate the sample size required to provide estimates that we can live with. They can help to prevent the confounding of the effects of two or more variables. And, finally, they can help optimize our data by providing the most information for the least amount of experimental effort. The role played by factorial experiments is well known for its capabilities toward this end, and there are even more efficient designs applicable in unique circumstances.

One of the shortcomings of the datasets used in the modeling of evaporative emissions is the limited number of vehicles. Though evaporative emissions are probably subject to less vehicle-to-vehicle variation than are exhaust emissions, it is highly desirable to remove vehicle effects from the effects of fuel properties and temperature cycles wherever possible. The data are not structured well to achieve this end, but in at least one situation, to be demonstrated later, vehicle differences can be removed with a very beneficial effect.

When data are sparse, it is even more imperative than usual to extract the most information from the limited amount of data available. An example, drawn from the data in this report, will be given in the next section, Data Analysis and Statistical Methodology.

Typically in this report a candidate regression model is fitted to the data and the coefficients are then tested for "significance." Those that fail the test are then dropped from the equation, the result being the same as if they were assigned the value zero. Still, by virtue of the principle of least squares, the "most likely" value of the coefficient is the one that was computed. This seeming impasse needs to be examined thoughtfully before arbitrarily rejecting the coefficient at 0.05 significance -- or 0.10, or 0.01 or 0.001, especially when the test is based on a small sample.

The obligation of the analyst, therefore, does not stop here. It is just as important to know the error bounds for the so-called significant coefficients as it is to know that some coefficients can seemingly be ignored. It is even more important to know error bounds for emission estimates computed by the regression equation. It should be kept in mind, too, that the precision of the estimates is not constant for all values of the predictor variables. It should be an obligation of the analyst to tell us how good the estimates are near the center of the sample space as well as how bad the estimates are near the edges of the sample space. The analyst can not just report significance and then "look the other way" when error bounds are so wide that emission estimates are essentially useless.

The present report does not provide this information, but it is admitted that it is not customarily to do so. Therefore, the author can not be faulted. To perform the necessary computations and prepare the required displays may not be practical under the constraints of the present report. That does not preclude, however, a broader look at the characteristics of estimates in future studies.

> *Error bounds in the form of 90 percent confidence intervals have been added to several of the tables (Tables 3, 6, and 7). Additionally, two tables of regression statistics have been added (Tables 4 and 5).*

4.0 DATA ANALYSIS AND STATISTICAL METHODOLOGY

It has been said that regression analysis is the most widely used and most widely misused of all statistical methods. Though an evident hyperbole, the statement contains an element of truth. Couched in the framework of General Linear Model (GLM), regression has wide appeal in a great variety of applications. The truth is, however, that regression analysis is not a universal solvent and is not without its shortcomings and pitfalls. In what follows, we examine Landman's analysis in the light of these considerations and suggest, wherever indicated, an alternative approach.

To say that a model is linear is simply to say that the response vector is a linear combination of a set of basis vectors. The basis vectors themselves, however, may be as "nonlinear" as they please and are often just the terms of a polynomial: 1, x, x2, x3, ... xn. The analyst's task is to determine coefficients for these terms so as to minimize the sum of squares of the residuals. He must also somehow select the terms to be included in such a way that the data are neither "underfitted" nor "overfitted." It is here that he resorts to R2 and to statistical tests of significance for each of the regression coefficients.

Although R2 is widely used as a measure of the efficacy of a regression model, it can be misleading. Moreover, it may not be realized that any number of models can be constructed to give exactly the same R2 and even exactly the same residuals point by point. Viewed in this light, the fact that there seems to be a good fit according to R2 is not necessarily a cause for rejoicing.

It must be kept in mind that R2 is a function of the residuals only at points where we have data and can tell us nothing about the response at points where we have no data. Unless we know how the function performs over its entire domain of definition, some of these functions, even the one we have selected, may oscillate radically between points at which we do have data. That is why it is important to know something about the geometry or hypergeometry of a regression equation before relying on it to interpolate between data points and sometimes to extrapolate beyond them.

Caution and common sense need to be exercised when evaluating regression models, whether by R2, t-tests of the regression coefficients or other means. That becomes clear if we examine Table 3 of the report and its accompanying text.

Randman notes that for each temperature cycle, diurnal emissions increase with fuel volatility and that for a given fuel, diurnal emissions increase as the temperature cycle increases. He might also have noted that the effect of temperature cycle on emissions is greater for the more volatile fuel, a fact that seems consistent with physical reasoning. Together, these three observations present an almost classic instance of a two-factor, factorial experiment in which response depends on both factors and their interaction.

> *The use of the VP_Product term was proposed (in report M6.EVP.001), in part, because it incorporates both of these two factors. Historically, it closely corresponds to the uncontrolled diurnal index (UDI) used in earlier versions of MOBILE but is easier to calculate.*

It is true that when emissions are regressed directly on prod and RVP, R-square is only 0.8593, whereas it is 0.9658 when log emissions are regressed on the same two variables. However, as shown below, R-square increases to 0.9000 for direct regression when the interaction term prod*RVP is introduced.

Without Interaction Term

	Coefficient	Std. Error	t
Constant	1.6273	2.0537	0.7924
Prod	0.0046	0.0012	3.9844
RVP	-0.4739	0.3192	1.4845

R-square = 0.8593

With Interaction Term

	Coefficient	Std. Error	t
Constant	7.7374	7.1024	1.0894
Prod	0.0046	0.0102	0.4457
RVP	-1.2253	0.8964	1.3669
Interaction	0.0011	0.0012	0.9014

R-square = 0.9000

Note that when the interaction term is added, the apparent significance of some of the other terms seem to decrease. The point to be noted here is that whether a term shows up as significant or not often depends on how many other terms are in the equation. When a term is dropped, the sum of squares associated with it are redistributed, partly to the error term but not entirely. Part of the ge redistributed terms are said to be aliased with other "significant" terms, and these aliases can be explicitly computed. Likewise, when additional terms are added to an existing equation, the order in which they are introduced can make a large difference in their "significance." The method of stepwise regression is an attempt to deal with this problem. Consequently, it may not be wise to rule out certain terms on the strength of their t-value alone.

Interaction terms were considered. Their use did provide an improved "fit" at the tested values. However, at intermediate values (i.e., RVPs between 7 and 9), the resulting predictions were not consistent with known responses. Therefore, EPA did not use them.

It also needs to be remembered that whether a term is called significant or not strongly depends on the significance level. Just because 0.05 is conventionally used does not make it sacrosanct. Often we are really more concerned with the Type II error than with the Type I and do not take advantage of the trade-offs between the two. That concern is no more recognized than in quality control and sampling acceptance plans. A sampling plan is designed to a specified consumer's risk and producer's risk. The consumer has to be protected to minimize the risk that he will accept a bad lot of material. But, the producer has to be protected against the risk that he will have a perfectly good lot rejected. A compromise that both can live with has to be found,

Similarly, in evaluating a regression coefficient, we need to know the consequences of retaining a coefficient when its effect really doesn't exist, but we also need to know the consequences of dropping a coefficient when its effect really does exist. By increasing the risk of a Type I error we can decrease the risk of a Type II error. Also, ruling out a term by rejecting it at any significance level says that that term is zero. However, we are willing to accept a coefficient with an extremely wide confidence interval and take no note of the fact. After all, the term is [sic] significant.

Which is the most appropriate model, with or without the logarithmic transformation of emission measurements?

Two factors bear on the answer to this question. One deals with the error distribution, the other with whether the effects of the pressure product term and RVP are additive or multiplicative.

If the variance of the observations that make up the mean diurnal emissions for each of the six means are proportional to the square of the means, then the log transformation may be appropriate, because it tends to stabilize the variances. (A constant variance is one of the requirements for regression.) However, if the variance already was stable (i.e., constant for all means), then the log transformation would tend to destabilize the variance and possibly lead to a biased result.

The log transformation also has another useful property. Each of the coefficients of the log model expresses the proportional, or percent change in emissions associated with a unit change in prod or RVP.

That variance increases as the level of emissions increases seems plausible and could be examined by computing the variance for each of the six categories. Also, whether effects are additive or multiplicative could be examined by comparing successive differences and successive ratios for the group means. At any rate, the log model seems effective. [As a matter of editorial note, the residual mean square in Table 3 should be 0.032764 not 0.32764.]

Another problem that may be encountered, as it was in the development of the Complex Model for Reformulated Gasoline (RFG), is the reversal of the sign of the slope (derivative) that characterizes the effect of a variable on emissions. Such a reversal can occur even when it is known from theory and experience that the function is monotonic non-decreasing or non-increasing. That is why one needs to know what the function looks like, particularly whether it makes any turns that are "counter-intuitive." For example, in the case of a quadratic, it is helpful to know where the zeros of the polynomial lie and even more important to know where the zeros of the derivative function lie.

Landman experienced the opposite of this effect in developing a model for diurnal emissions. In Table 4, he uses an equation containing only a constant and a cubic term. His rationale for the choice, in his words, is as follows:

> In Section 4.2.1, we noted that the diurnal emissions for the vehicles with properly functioning evaporative control systems were not a strictly increasing function of the VP product term. However, for the vehicles that failed the pressure test, the diurnal emissions increased as the VP product increased. We, therefore, repeated the approach used in earlier analyses of regressing the diurnal emission emissions against the cube of the VP product term producing Table 4.

It is not clear how the lack of monotonicity leads to the conclusion that a cubic function of the product term, referred to hereinafter as prod, is most appropriate. It turns out that, over the range of the data, prod1, prod2, prod3 and even prod4 are highly correlated, the coefficient of correlation between pairs of these variables ranging from 0.92 to 0.98. It follows, then, that any of the prod functions might perform about as well as any other. This fact becomes evident when other powers of the product term are used as the basis of the model, as will be shown below.

There may be a more cogent reason, however, for the lack of monotonicity. For a product term to give consistent results, it is necessary for the product to exhibit reciprocity. Let us call the two factors that make up the product xä1ä and xä2ä. All pairs of xä1ä and xä2ä that map into a given value of prod should produce the same effect on evaporative emissions. Otherwise, inconsistencies may arise.

According to equation (3) of the Randman paper, xä1ä is simply the range of vapor pressure for the day, and xä2ä is simply the midrange of the day's vapor pressure. In the present notation, the product term is defined as

prod = 1/2 [(xä1ä - xä2ä) * (xä1ä + xä2ä)]

or

prod = 1/2 (xä1ä2 -xä2ä2)

Consequently,

prod3 = 1/8 (xä1ä2 - xä2ä2)3

When this expression is expanded, it can be seen that powers of vapor pressure as high as six will be encountered. More importantly, for reciprocity to hold, the same emissions should be associated with a given value of prod3, whether that value was produced by - say - a short VP range combined with a high midrange or long range combined with a low midrange. Table 4, however, being based on the data in Appendix C, has other difficulties. One of the vehicles, #5044, shows zero diurnal emissions for all conditions except one, and that one shows a value far out of line with the same condition of the other vehicles. It is no wonder that R2 is only 0.411! A look at a plot of the residuals would make that fact quite clear, and it is for reasons such as this that residuals should be examined to see if there is any indication of "lack of fit" such as outliers or trends.

Suppose, now, that we remove vehicle #5044 and recompute the regression. Then we get:

Constant = 10.6634
Coefficient of prod3 = 0.0171
R2 = 0.87

It is clear that the one vehicle strongly biases the results. It is also clear that different vehicles exhibit different responses and that vehicle effects should be removed in the analysis if possible.

Actually, the data are ideally suited for removing vehicle effects by means of dummy variables. Below, regression results are given for individual vehicles, as well as for meaningful subsets of the data in Appendix C.

HOW VEHICLE EFFECTS MODIFY THE MODEL FOR DIURNAL EMISSIONS

Vehicle Set	Constant	Coef. of prod3	R2
All	7.9460	0.01300	0.4106
All but #5044	10.6634	0.0171	0.8742
Vehicle #5008	14.7713	0.0186	0.9735
Vehicle #5021	11.3437	0.0137	0.9425
Vehicle #5044	-0.2064	0.0006	0.8745
Vehicle #5067	5.8753	0.0191	0.9490
Best choice*	7.2744	0.0171	0.9422

*Vehicle #5044 omitted, vehicle effects removed

Note that by simply excluding one vehicle from the analysis and removing the effects of vehicles we go from R2 of 0.41 to 0.94 and even up to 0.97 for individual vehicles.

Now that we have found a consistent set of data - namely, the set of data with vehicle #5044 removed - let us try various powers of the product term as predictor variable, as well as various combinations of those powers. The resulting values of R2 are listed below.

INSENSITIVITY OF PRODn IN PREDICTING DIURNAL EMISSIONS

Power, n	R-square
1	0.8421
2	0.8820
3	0.8742
1&2	0.8836
1&3	0.8821
2&3	0.8830
1&2&3	0.8848

As conjectured, it little matters what power of the product term is used, or what combination of powers; the resulting prediction capability, as judged by R2, seem to be about the same.

5.0 APPROPRIATENESS OF THE CONCLUSIONS

Though not called out explicitly, conclusions are found in the Summary section of Landman's report. They can be listed, briefly, as follows.

1. Separate estimates of diurnal and rest loss emissions are given for "gross liquid leakers" and vehicles subject only to vapor losses. Liquid losses per hour are estimated as a constant; vapor losses are estimated by means of a relatively simple empirical equation,

2. A major predictor variable, called "prod" in this review, is the product of two vapor pressures and is said to take into account both vapor pressure and temperature. For some equations prod may be raised to the second or third power; it may also be modified, in some cases, by additional variables, notably RVP.

3. Separate estimates are provided for various vehicle strata, the strata being defined by whether the vehicle passed or failed the purge and/or pressure tests.

4. Evaporative emissions are assumed to be zero for temperatures below 40^{o}F and for any temperature cycle in which the temperature stays relatively constant. The term "constant" is defined as not varying more than a few degrees from the mean temperature.

How appropriate are these conclusions?

To put into perspective what is expected of the evaporative emission estimates, let us consider the estimate for gross liquid leakers. A single number is supposed to represent emissions from vehicles of all ages, all places and all climates, all drivers and all lifestyles ... and so on. How close can the estimate be to "truth," when only a few vehicles are tested and the results are scaled up according to the relative frequency of somewhat arbitrarily designated "strata" that also had to be estimated.

The answer is probably "Not very," but the report provides no clue, however vacuous, of just how "very" is very.

> *These points are addressed in the parallel report devoted to these vehicles with substantial leaks of liquid gasoline (i.e., report number M6.EVP.009, entitled "Evaporative Emissions of Gross Liquid Leakers in MOBILE6").*

Now consider how much more complicated and subject to error are the estimates provided by an empirical equation based on "an educated guess" of what form that equation should take and what predictor variables it should contain. The problem is aggravated by the fact that the precision of the estimate varies widely over the range of the predictor variables. Then add the uncertainty of the strata weights and ... but, enough already!

EPA and Mr. Landman are to be commended for having the courage to accept such a mammoth challenge, but their accomplishments would gather infinitely more kudos if they could assure us that their estimates are within 5% of real-world truth. Admittedly, to be able to say how good their estimates are is an even more difficult problem than to compute those estimates in the first place. But ... unless we have some measure of how good the estimates are, we might just as well not have computed them at all!

The form of the predictive equations and the validity of the predictor variables are subject to question on several counts. The product term is particularly open to criticism. Probably it has a factual or theoretical basis not known to this reviewer, but if so, it is difficult to understand the indifference of this term to what power it is raised to.

> *If test results had been obtained over a <u>wider</u> range of this VP_Product term (e.g., using 11.0 RVP fuel over an 82-106 degree cycle), then the exponent used would seem less "indifferent."*

More important, perhaps, is the matter of reciprocity. For any given value of prod, there is an infinitude of pairs of factors that map into that value. For the prod function or powers of that function, all pairs should yield the same evaporative emission estimates.

> *In general, EPA chose the lowest power (exponent) that would explain the observed results (i.e., the simplest explanation).*

There are two instances in which the proposed models exhibit a step function. At temperatures below 40° F. emissions are taken as zero. Though this estimate may be reasonable, "Nature abhors a vacuum." Likewise, engineers and mathematicians are not comfortable with discontinuities unless there is good reason for those discontinuities to occur. A similar impasse is faced in defining emissions to be constant if the range of the temperature cycle is zero, or within a few degrees of zero. Means exist for smoothing these discontinuities and even, perhaps, for assuring that the derivative of the function exhibits no discontinuities.

> *Using a smooth curve rather than abruptly setting the emissions to zero is appealing. However, the actual differences in the resulting fleet emissions are too small to be meaningful.*

Finally, we come to the practical matter of applying these models to real-world situations. Inasmuch as some twenty or so equations are provided, there must be means for selecting the one that is uniquely appropriate for the particular problem at hand. This fact seems to assume that the vehicle or vehicles under consideration have already been purge and pressure tested as well as examined for liquid leaks. So far as the use of the models for compiling an emission inventory for the present fleet is concerned, there would seem to be no problem. However, in future applications, classification of vehicles would have to be a precursor to application of the models.

> *Since the in-use fleet actually contains all of these strata, <u>all</u> of these equations (as well as many others) are used in MOBILE6. The resulting predictions are then weighted together. (See parallel report number M6.EVP.006, entitled "Estimating Weighting Factors for Evaporative Emissions in MOBILE6.")*

6.0 RECOMMENDATIONS FOR ANY ALTERNATE DATASETS AND/OR ANALYSES

The ideal dataset would be one in which vehicles are recruited in accordance with a sampling plan and experiment design tailored to the requirements of the moment. Some replication should be built into the plan to allow estimation of errors attributed to "unassignable causes." These are the errors that remain after we have identified and estimated all the fixed effects that we could think of. In addition, the design should be such that the relative magnitude of those "fixed effects" are not confounded with errors due to the unassignable causes.

The prod variable needs to be examined in depth, with regard to reciprocity and correlation of successive powers, as well as whether there are other variables that might better serve the purpose. If there is a theoretical reason for using a term as complex as prod3, it should be revealed.

A particular objective that should be the goal of any experiment design is to choose variables and the levels of those variables in such a way that they are orthogonal. This type of design assures that the estimates of the effects of all variables are completely independent of each other.

With regard to discontinuities in the models, means should provided for "fairing the curve" so that it blends smoothly into both the top and bottom of the step. A method for realizing such smoothing by means of exponential was suggested in work connected with development of the Complex Model.

It is recommended that the above changes be incorporated in the present report to whatever degree is practical within allowable time and resource constraints. Although a complete assessment of error limits is beyond the scope of the present report, there does exist enough information to make a start on this very important issue. Most statistical software gives as output the standard error of regression coefficients and the standard error of estimate at various points in the predictor space. It is recommended that some effort be made in this direction, if only to show the general magnitude of the errors. In future studies, effort should be made toward continued refinement of the error bounds.

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Appendix H

Response to Peer Review Comments from Sandeep Kishan

This report was formally peer reviewed by two peer reviewers (H. T. McAdams and Sandeep Kishan). In this appendix, comments from Sandeep Kishan are reproduced in plain text, and EPA's responses to those comments are interspersed in indented italics. Each of these comments refer to page numbers in the earlier draft version (dated July 1, 1999) that do not necessarily match the page numbers in this final version. Comments from the other peer reviewer appear in the preceding appendix (Appendix G).

> *It is important to note that this final version of the report has changed substantially from the draft version that Sandeep Kishan reviewed. In that earlier version, the goal was to develop equations that would predict the diurnal and resting loss emissions of these ETP vehicles. In the interim between these versions of this report, we realized that the predicted results (from that draft) were comparable to the MOBILE5 predictions. Therefore, in this final version, our goal changed and became the testing and validation of those MOBILE5 predictions.*

> *This change of direction resulted in many of Sandeep Kishan's comments no longer being applicable. However, all of his comments were considered, and those that were still applicable were incorporated.*

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This memorandum provides peer review comments on two EPA documents: "Evaluating Resting Loss and Diurnal Evaporative Emissions Using RTD Tests", Document No. M6.EVP.001, November 20, 1998 and "Modeling Diurnal and Resting Loss Emissions" Report Number M6.EVP.005, October 1, 1998. Both of these are draft reports.

> *The original peer review covered two of the MOBILE6 documents. Only the portion of that review pertaining to this report is reproduced below in this appendix. The remainder of the peer review is reproduced in report number M6.EVP.001 (Appendix I of that report).*

Overall, we think that the reports are good, and they present some new data analysis techniques that are attractive. Since, in the past, we have had to do similar data analyses and modeling for evaporative emissions from vehicle test data, we can appreciate many of the difficulties and data limitations you are subject to. We hope the comments below help you with this effort.

Document No. M6.EVP.005 (October 1, 1998)

This report was clearly written and the stratification seems to be appropriate for this analysis. We think that the dataset used is discouraging but it may be that no alternate datasets can be found for this purpose. Therefore, we think that it is important to let the reader know that you are committed to revisiting these relationships when new data does become available. We also have the same concern with the regressions in this report as with those already discussed for the previous report.

1. Page 3, end of Section 1.0 – It might be appropriate to state that the models developed in this report are intended to be a temporary patch for MOBILE6 until EPA or someone else gets actual vehicle measurement data on the effects of RVP, temperature, and purge and pressure status on the evaporative emissions.

   A statement to that effect has been added.

2. Page 5, Section 3.0 – You are proposing to use 1990 to 1995 model year vehicle data to estimate the effects of temperature, RVP, and purge and pressure status on trends in the 1996 and 1997 vehicles. What evidence do you have that the failure modes of 1996 and 1997's will be like the failure modes of 1990 to 1995's? Are the materials, connectors, etc., the same? Consider the five bulleted items in Section 1.0; we think you need some discussion about why these trends and these slightly older vehicles would be similar to those in the 1996 and 1997 vehicles.

   The reviewer is correct; the evidence that these vehicles are comparable to the ETP vehicles is lacking. However, until we obtain test data on in-use ETP vehicles, this data set is the best we have to work with.

3. Page 10, Section 4.1.2, bottom of the page – During the regression of estimated resting losses versus temperature for different vehicles, it was found that the r^2 for the regression of resting losses versus temperature produced a low r^2 and a temperature coefficient that was not statistically significant. Rather than averaging the resting loss emissions for all 12 cars together, it would be more appropriate to use a categorical variable for the identity of the cars. This will produce a larger r^2 since the researcher recognizes that it's the differences among the cars that produce most of the variability in the dataset. The result will be a good estimate for the slope on the temperature and, possibly, also make the temperature coefficient statistically significant.

With the changes made to this revision, this comment is no longer applicable.

4. Page 10, Section 4.1.2, paragraph 2 – You had data describing resting loss emissions for the two separate strata – one where vehicles failed the pressure test and one where vehicles failed the purge test. Why didn’t you just use those individual strata results to predict the temperature effect on resting losses for those type of malfunctions? The data values in Appendix D look reasonable for the vehicles in those strata. Instead, these strata were combined and then modeled. Why?

   With the changes made to this revision, this comment is no longer applicable.

5. Page 12, Section 4.2.1 – By performing the regression on diurnal emissions on the average emissions of vehicles, data from only five vehicles could be used. However, if instead, the regression had been performed on the individual emission values of the vehicles, 12 vehicle’s data would supply information to the regression about temperature and RVP relationships. Thus, the choice of performing regressions on averages rather than on individual values causes the resulting model to lose information which could have been provided by an additional seven vehicles. If the regressions are performed in SAS, a class variable for vehicle can be used to account for an unbalanced set of data with respect to vapor pressure product and RVP. The resulting coefficients for RVP and vapor pressure product would be better estimates of the true relationships.

   With the changes made to this revision, this comment is no longer applicable; however, this suggestion will be used in future analyses.

6. Page 15, Section 4.2.2 – In Appendix C, one vehicle also has measurements at 6.3 psi fuel RVP. Why did you not use these values in your regressions? If you use a class variable for vehicle identification, the information from these three additional measurements can be brought into the regression.

   The data at 6.3 psi were incorporated in this latest revision.

7. The use of the cube of the vapor pressure product in this regression is troubling. What evidence do you have that the cube is the appropriate transformation? It seems to us that since a class variable for vehicle identification was not used, it is unlikely that the cube transformation is correct.

With the changes made to this revision, this comment is no longer applicable.

8. Page 27, Appendix C – Note that for five of the six diurnal emissions calculated for vehicle Number 5044, the values are zero. This is evidently because the estimated daily resting loss was greater than the measured RTD grams. The zero values for this vehicle were not mentioned in the text in Section 4.2.2. How are these zero values handled in the regression summarized in Table 4?

   With the changes made to this revision, this comment is no longer applicable.

9. Page 17, Section 4.2.3 – The analysis has available eight vehicles to perform the regression. All eight vehicles could be used in the regression instead of using only five vehicles. Again, if class variables are used for the identification of each variable, SAS can use all the information to determine regression coefficients for the input variables. The result would be better estimates of the coefficients.

   With the changes made to this revision, this comment is no longer applicable; however, this suggestion will be used in future analyses.

10. We would like to see some plots of the raw data versus the values of input variables in the model or versus temperature and RVP.

    The reader can easily plot the data in this report if such graphs are desirable.

11. Diurnal emissions for vehicles passing the purge and pressure test were transformed to logs and then regressed while vehicles that failed the purge and/or pressure tests were regressed without taking the logs. What evidence do you have for taking these different approaches? In general, we would expect the log of the diurnal emissions to be a better approach to take than the cube of the vapor pressure product. A discussion of the engineering aspects of the system under different purge/pressure result conditions could lead to a resolution.

    With the changes made to this revision, this comment is no longer applicable.

12. It seems that this whole report is based on measurements taken on the wrong model year vehicles. We presume that the intent in doing this is to provide some sort of

functionality in the MOBILE model for the 1996 to 1997 model years using 1990 to 1995 vehicle data but only until the data actually taken on 1996 and newer vehicles can be obtained and analyzed. You might consider adding a statement that says that when this new data does become available, these models will be revisited.

A statement to that effect has been added to the end of Section 1 (page 3). This comment is similar to this reviewer's first comment.

Appendix I

Response to Written Comments from Stakeholders

The following comment was submitted in response to EPA’s posting a draft of a related report (M6.IM.003) on the MOBILE6 website. The full text of this comment is posted on the MOBILE6 website.

Comment Number: 102

Name / Affiliation: David Lax / API

Date: January 25, 2000

Comment:

Under the heading of:

"Adjustments for Enhanced Evaporative Vehicles

"To account for the improved durability of enhanced evap control systems, EPA reduced the baseline failure rates by 50%. They did this to both non-cap and cap failures. This approach is appropriate for non-cap failures. (Although some manufacturers went with ¼ turn caps, e.g., Ford and possibly some GMs.) As mentioned above, the big change in cap technology occurred in the mid-80s with the switch to screw-in caps, and this is not accounted for in EPA’s estimates."

EPA’s Response:

In the report actually being commented on, the pressure failures were divided into those related to the fuel cap and those not involving the fuel cap. While that breakdown is not used in this report, it is encouraging that API agrees that it is appropriate to estimate the failure rate (on the pressure test) of the ETP vehicles by reducing the failure rate of the pre-ETP vehicles.