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

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

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ABSTRACT

This document reports on EPA's proposed methods of estimating the resting loss and diurnal emissions from vehicles certified to the enhanced evaporative standards (i.e., some 1996 through 1998 and all 1999 and newer vehicles). Since this draft report is a proposal, its analyses and conclusions may change to reflect comments, suggestions, and new data.

Please note that EPA is seeking comments that might aid us in modeling any aspect of resting loss or diurnal evaporative emissions.

Comments on this report and its proposed use in MOBILE6 should be sent to the attention of Larry Landman. Comments may be submitted electronically to mobile@epa.gov, or by fax to (734) 214-4939, or by mail to "MOBILE6 Review Comments", US EPA Assessment and Modeling Division, 2000 Traverwood Drive, Ann Arbor, MI 48105. Electronic submission of comments is preferred. In your comments, please note clearly the document that you are commenting on, including the report title and the code number listed. Please be sure to include your name, address, affiliation, and any other pertinent information.

This document is being released and posted. Comments will be accepted for sixty (60) days from the posting date. EPA will then review and consider all comments received and will provide a summary of those comments, and how we are responding to them.

DRAFT

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 emissions estimated in the MOBILE model. In recently released draft reports (M6.EVP.001 and M6.EVP.002), the US Environmental Protection Agency (EPA) proposed methods of estimating resting loss and diurnal emissions from 1995 and older model year vehicles. These estimates were 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 twenty percent of their vehicles using a new "enhanced" evaporative testing procedure; that percentage is scheduled to increase to one hundred percent by the 1999 model year. The phase-in percentages are given below in Table 1 (copied from 40 CFR 86.096-8).

Table 1

Phase-In of Vehicles with Enhanced Evaporative Controls

Model Year	Percentage
1995	0%
1996	20%
1997	40%
1998	90%
1999	100%

In order to meet the enhanced evaporative standards, manufacturers have implemented a number of changes, including (but 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 proposes to use a separate set of estimates of both resting loss and diurnal emissions for these vehicles.

Unlike the analyses for older vehicles that were based on results of tests of in-use vehicles, the analyses in this report generally are <u>not</u> based on testing of these in-use 1996 and newer vehicles because EPA has very few test results on that segment of the in-use fleet. In this report, EPA proposes methods of estimating the resting loss and diurnal emissions from these in-use 1996 and newer vehicles based on RTD testing of older but similar vehicles.

2.0 Data Sources

EPA proposes to base its estimates of resting loss and diurnal emissions on the results of real-time diurnal (RTD) tests. At the time of this analysis, EPA had two available sources of RTD test data on vehicles that were certified to the new evaporative standards:

1) a summary of RTD testing used by the ARB and by the EPA to certify new (1996-97 model year) vehicles (30 and 35 vehicles, respectively) 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).

However, the test data (from these two sources) on the 1996 and newer vehicles have two 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, EPA's analysis is limited by not having 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). Since, all the RTD testing performed on these 1996 and newer vehicles had been run at a single combination of temperature cycle and fuel volatility, EPA is limited in using those data to predict evaporative emissions at other combinations of temperature cycle and fuel volatility.

To compensate for those significant limitations, EPA proposes to supplement those data with the results of RTD testing of older vehicles that were not certified to the enhanced evaporative standards. Two sources of those 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 the 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 were performed over three different temperature cycles and using fuels with different RVPs.

A fifth source of information on these vehicles certified to the enhanced evaporative standards was:

5) an analysis of evaporative emissions (not explicitly based on RTD testing) of vehicles certified to the enhanced evaporative standard presented to the California Air Resources Board (ARB) (in December 1997) by the American Automobile Manufacturers Association (AAMA) and the Association of International Automobile Manufacturers (AIAM).

In Section 3.0, EPA proposes how to use 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 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 this time 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, proposes to use results of RTD tests on older 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 proposes to continue (from the previous analyses) the approach of dividing the in-use fleet into four strata. The first of these 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 that such a definition could result in potentially ignoring a vehicle having a substantial leak that is apparent only when the engine is operating (e.g., some fuel line leaks).

While neither the purge test nor the pressure test measures evaporative emissions, a vehicle’s failure 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. EPA proposes to use the results on the purge and pressure tests to define the remaining three strata. This approach produces the following three additional strata each containing:

1) vehicles that pass <u>both</u> the purge and pressure tests,

2) vehicles that fail the pressure test (regardless of their performance on the purge test), and

3) vehicles that fail <u>only</u> the purge test.

As discussed previously, it is necessary to make use of the RTD tests performed on older 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. (RTD tests on a total of 25 vehicles were found and appear in Appendix A.)

2) RTD tests were performed on 65 1996-97 model year (enhanced evaporative procedure certified) vehicles using a daily temperature profile in which the ambient temperatures cycled between 72 and 96 degrees with a fuel having an RVP of 9.0 psi (data source number 1). EPA proposes to use those test results to obtain baseline evaporative emissions for these "properly functioning" vehicles for that specific temperature cycle and for that test fuel. To "correct" those baseline values for temperature and RVP changes, EPA identified, in its RTD data base (data source 3), ten 1990-95 model year PFI vehicles that:

    - passed both the purge and pressure tests,
    - had a RTD test performed using a daily temperature cycle ranging between 72 and 96 degrees with a fuel having an RVP of 9.0 psi (i.e., at the baseline conditions used for the vehicles in data source 1), and
    - had one or more additional RTD tests performed using a fuel with an RVP of 6.8 psi.

3) EPA believes that the RTD emissions from <u>malfunctioning</u> 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 the 13 failing only the purge test and the remaining five failing the pressure test). (See Appendices B and C, respectively.) EPA proposes to use these 13 vehicles to estimate the effects on both the resting loss and diurnal emissions for the malfunctioning enhanced evaporative control vehicles of changes to the temperature cycle and/or to the RVP of the fuel.

4.0 Analysis

As noted in two previous reports (M6.EVP.001 and M6.EVP.002), EPA proposes to use 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 which 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.

This approach permitted EPA to analyze separately the relatively constant resting loss emissions and the (pressure driven) diurnal emissions.

4.1 Resting Loss Emissions

4.1.1 Resting Loss Emissions of Properly Functioning Vehicles

In Section 3.0, EPA proposed using data from 10 of the older (1990-95) model year vehicles to characterize the effects on the baseline evaporative emissions of altering either the temperature cycle or the fuel RVP for the 1996 and newer model year vehicles with properly functioning evaporative control systems. Since the resting loss emissions were calculated as the average hourly emissions during hours 19 through 24 of the RTD test, to calculate the baseline resting loss emissions (from the RTD tests of the 65 vehicles in data source 1) we need the emissions to be measured and reported hourly (or at least in six hour intervals). Unfortunately, the test results in data source 1 were reported for each 24-hour period; therefore, EPA does not currently have the necessary baseline resting loss data for that stratum. Thus, EPA must determine not only the correction factors but also the baseline resting loss values.

EPA believes that, while that sample of 10 vehicles (proposed in Section 3.0) is appropriate for estimating the <u>effects</u> of varying either the temperature cycle or fuel RVP, the actual emission values are not necessarily representative of actual 1996 and newer vehicles. Hence, those vehicles might not be appropriate for estimating the baseline resting loss emissions. To find an appropriate subset of the 10-vehicle sample composed of vehicles whose emissions are representative of the 1996 and newer vehicles, we examined the data from the 65 certification vehicles (from data source 1). Those vehicles had a mean RTD emission for the first 24-hours of a 72-hour RTD test of 0.745 grams (for a temperature cycle from 72 to 96 degrees and with a 9.0 RVP fuel). The corresponding median RTD for those 65 tests was 0.635 grams. In the 10-vehicle sample, the five vehicles that had RTD emissions of at most 1.0 grams (over the same temperature cycle and using the same test fuel) had mean and median RTD emissions of 0.726 and 0.653 grams, respectively. This sample of five vehicles consisted of four light-duty vehicles and one light-duty truck. Based on the similarity of RTD emissions as indicated by both the means and medians of the 65-vehicle sample and this five-vehicle sample, EPA proposes to use the smaller sample to estimate both the baseline and the temperature corrections of the hourly resting loss emissions of the properly functioning 1996 and newer vehicles.

We then estimated the hourly resting loss associated with 60, 72 and 82 degrees Fahrenheit for each of those five vehicles (see Appendices A and D) and regressed the resting loss emissions against the ambient temperatures to obtain Table 2. A linear (rather than exponential or polynomial) regression was used for consistency with the modeling of resting loss emissions of the pre-1996 vehicles (see reports M6.EVP.001 or M6.EVP.002).

Table 2

Linear Regression of Hourly Resting Loss Emissions (Vehicles Passing Both Purge and Pressure Tests)

Dependent variable is: **Resting Loss**

No Selector

R squared = 40.2%   R squared (adjusted) = 35.6%
s = 0.0061 with 15 - 2 = 13 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	0.000320	1	0.000320	8.72
Residual	0.000477	13	0.000037	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	-0.027859	0.0125	-2.23	0.0441
Temperature	0.000514	0.0002	2.95	0.0112

Converting that linear regression analysis into an equation produces equation **(1)** below:

Hourly Resting Loss (grams/hr) = -0.027859 + [0.000514 * Temperature (°F)] **(1)**

EPA proposes to use equation **(1)** to estimate the hourly resting loss emissions (in grams per hour) of that portion of the fleet of 1996 and newer model year vehicles with properly 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 or equal to 54.2 degrees Fahrenheit. EPA will assume that the resting loss emissions at those temperatures will be zero grams per hour.

Equation **(1)** also predicts that the mean hourly resting loss emissions (for the fleet of 1996 and newer model year vehicles with properly functioning evaporative control systems) at 72 degrees Fahrenheit would be 0.009149 grams per hour. Repeating that calculation for <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 for the fleet of 0.3596 grams per vehicle. Subtracting that value from the mean RTD test results (0.745 grams per day) yields total diurnal emissions of 0.385 grams per vehicle per day (which will be used as the baseline diurnal emission in Section 4.2.1).

4.1.2 Resting Loss Emissions of Malfunctioning Vehicles

In Section 3.0, EPA proposed using five 1990-95 model year vehicles to represent the 1996 and newer model year vehicles that failed the pressure test (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 Appendix D). Repeating the approach used with the vehicles passing both the purge and pressure tests, we estimated the hourly resting loss associated with ambient temperatures of 60, 72 and 82 degrees Fahrenheit for each of those 12 vehicles that were tested over all three temperature cycles. We then regressed the resting loss emissions against the ambient temperatures within each of these two strata:

- the stratum represented by the four vehicles failing the pressure test (see Appendices C and D) and

- the stratum represented by the eight vehicles failing the purge test (see Appendices B and D).

Additionally, we combined the test results on all 12 vehicles to create the single stratum of vehicles failing either the purge or the pressure test, and we again regressed the resting loss emissions against the ambient temperatures within that third stratum.

In each of those three strata, the differences in resting loss emissions from vehicle-to-vehicle exceeded the differences in emissions resulting from changes in ambient temperature. This resulted in each regression analysis producing both low R-squared values and indicated that temperature was not a statistically significant variable (an unlikely situation). In order to obtain a model for hourly resting loss emissions based on temperature, we attempted to reduce the effect of the vehicle-to-vehicle variability by averaging the resting loss emissions for all 12 vehicles at each of the three temperatures (i.e., producing only three temperature / resting loss pairs) and then regressing those three data points. This regression produced an R-squared of 100.0 percent. Since MOBILE6 is designed to predict only the mean emissions, EPA proposes to use this regression to estimate the means of the hourly resting loss emissions (in grams per hour) of the 1996 and newer model year vehicles with malfunctioning evaporative control systems. Converting that linear regression analysis into an equation yields:

Hourly Resting Loss (grams/hr) = -0.076535 + [0.001603 * Temperature (°F)] **(2)**

Equation **(2)** predicts that the mean hourly resting loss emissions (for the fleet of 1996 and newer model year vehicles with malfunctioning evaporative control systems) will be negative for all ambient temperatures below 47.8 degrees Fahrenheit. EPA will assume that the resting loss emissions at those temperatures will be zero grams per hour.

4.1.3 Resting Loss Emissions of "Gross Liquid Leakers"

In a previous 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 a constant 8.84 grams per hour. EPA proposes to continue that assumption for the 1996 and newer vehicles that were certified to the enhanced evaporative standard.

4.2 Diurnal Emissions

In Section 4.1, equation **(1)** indicates that for each one degree (Fahrenheit) increase in ambient temperature, there is a corresponding increase of 0.000514 grams per hour in the hourly resting loss emissions. Applying that temperature correction 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). This approach predicts that the full day's resting loss emissions (in grams) would be 24 times the hourly resting loss (calculated at the day's low temperature) plus 0.140 grams. Subtracting that quantity from each of the RTD test scores of the ten properly functioning vehicles yields the estimated diurnal emissions on each of the 48 RTD tests on those 10 vehicles.

Repeating this procedure for the 13 malfunctioning vehicles but using the coefficient (0.001603) from equation **(2)**, predicts that the full day's resting loss emissions (in grams) would be 24 times the hourly resting loss (calculated at the day's low temperature) plus 0.437 grams. Subtracting that quantity from each of the RTD result score of the 13 malfunctioning vehicles yields the estimated diurnal emissions.

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 previous reports (M6.EVP.001 and M6.EVP.002), we created a single parameter that incorporated all of those factors. That new parameter is based on the fuel's vapor pressure (VP). 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)**.

$$VP\_Product\_Term = (VP_{HIGH} - VP_{LOW}) * (VP_{HIGH} + VP_{LOW}) / 2 \qquad \textbf{(3)}$$

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 earlier reports modeled the diurnal emissions as functions of both that VP product term and the RVP of the test fuel.

4.2.1 Diurnal Emissions of Properly Functioning Vehicles

In Section 3.0, EPA proposed using the 25 1990-95 model year vehicles listed in Appendix A to model the diurnal emissions from the 1996 and newer model year vehicles with properly functioning evaporative control systems. However, only five of those 25 vehicles were tested at each of the six possible temperature and RVP combinations. (While a sample of five vehicles is relatively small, the disadvantages of that small size are offset by having the identical sample of vehicles at each of those six testing combinations which eliminates some of the problems caused by having test results on a different group of vehicles at each of those combinations.)

The approach used in the earlier reports was to first regress the mean diurnal emission emissions against the RVP of the test fuel combined with either the VP product term (in kiloPascals squared) or the square of that product term. Those six mean values (for the five vehicles) are given in the following table.

Temperature Cycle	Fuel RVP	VP_Product Term	Mean Diurnal
60 to 84	6.8	375	0.616
72 to 96	6.8	567	0.768
82 to 106	6.8	789	1.781
60 to 84	9.0	655	0.535
72 to 96	9.0	969	1.084
82 to 106	9.0	1,324	4.008

These means do confirm two reasonable patterns:

- For each temperature cycle, as the fuel volatility increases, so do the diurnal emissions.
- For a given fuel, as the temperature cycle increases, so do the diurnal emissions.

This confirms that the diurnal emissions, rather than being a function of the VP product term alone, might be a function of that term in combination with the fuel RVP or temperature cycle. A number of different combinations were tested, and the one that proved most successful in predicting the diurnal emissions was a regression of the logarithm diurnal emissions against:

- the RVP of the test fuel (in psi) and
- the vapor pressure product term (in kiloPascals squared).

The results of that regression analysis are given in Table 3.

Table 3

Linear Regression of Mean Diurnal Emissions (Vehicles Passing Both Purge and Pressure Tests)

Dependent variable is: **Ln_Diurnal**

No Selector

R squared = 96.6%   R squared (adjusted) = 94.3%
s = 0.1810 with 6 - 3 = 3 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	2.78802	2	1.39401	42.5
Residual	0.098293	3	0.32764	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	0.860614	0.5792	1.49	0.2340
VP_Product	0.002905	0.0003	8.94	0.0030
RVP	-0.381496	0.0900	-4.24	0.0241

In the analyses performed in the previous reports, after we completed the regression analysis, we then modified the constant term (produced by the regression) so that the resulting curve would pass through the mean of all the relevant data (i.e., in this case, through the mean of the 65 certification RTD tests at the single temperature / RVP combination). In Section 4.1.1, we estimated that 0.385 grams per vehicle per day was the baseline value of the diurnal emissions of the properly functioning 1996 and newer vehicles. Modifying the constant term in the preceding regression equation so that curve passes through that baseline value (over the 72 to 96 degree cycle using 9.0 RVP fuel) produces the equation:

$$\text{24-Hour Diurnal (grams)} = \exp\left[-0.33599 + (0.002905 * \text{VP\_Product\_Term}) - (0.381496 * \text{RVP}) \right] \quad \textbf{(4)}$$

EPA <u>proposes</u> to use equation **(4)** to estimate the 24-hour diurnal emissions of all 1996 and newer model year 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 proposes to calculate the diurnal 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.

4.2.2 Diurnal Emissions of Vehicles Failing the Pressure Test

In Section 3.0, EPA proposed using five 1990-95 model year vehicles to model the diurnal emissions from the 1996 and newer model year vehicles that failed the pressure test (Appendix C). Only four of those five vehicles were each tested using the same two fuels (i.e., the 6.8 and 9.0 psi RVP fuels) over each of the three temperature cycles (i.e., the 60 to 84, the 72 to 96, and the 82 to 106 degree cycles). Thus, at the six different combinations of temperature cycle and fuel RVP there were a total 24 measurements of diurnal emissions. 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 term increased. We, therefore, repeated the approach used in the earlier analyses of regressing the diurnal emission emissions against the cube of the VP product term (in kiloPascals squared), producing the Table 4. (As a check, we ran other regressions that included RVP as one of the variables along with the vapor pressure product term. In none of them was RVP identified as being statistically significant.)

Table 4

Linear Regression of Diurnal Emissions (Vehicles Failing the Pressure Test)

Dependent variable is: **Diurnal**

No Selector

R squared = 41.1%   R squared (adjusted = 38.4%

s = 12.56 with 24 - 2 = 22 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	2417.79	1	2417.79	15.3
Residual	3470.15	22	157.734	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	7.94455	3.475	2.29	0.0322
Cube of VP_Product / 1,000,000	0.013004	0.0033	3.92	0.0007

We then modified the constant term (produced by the regression) so that the resulting curve would pass through the mean of all the relevant data (i.e., all 28 tests on the five vehicles at nine temperature / RVP combinations). This produced the following equation:

24-Hour Diurnal (grams) = 7.804751 + [0.012985 * Cube of VP_Product] / M **(5)**

Where M = 1,000,000

EPA proposes to use equation **(5)** to estimate the mean 24-hour diurnal emissions of all 1996 and newer model year vehicles that failed the pressure test with the following two modifications (repeated from Section 4.2.1):

1) Regardless of the increase in ambient temperatures, there are no diurnal emissions until the 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 proposes to calculate the diurnal 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.

4.2.3 Diurnal Emissions of Vehicles Failing Only the Purge Test

In Section 3.0, EPA proposed using eight 1990-95 model year vehicles to model the diurnal emissions from the 1996 and newer model year vehicles that failed only the purge test. Only five of those eight vehicles were each tested over the six different combinations of temperature cycle and fuel RVP. Thus, at the six different combinations of temperature cycle and fuel RVP there were a total 30 measurements of diurnal emissions. Repeating the approach used in Sections 4.2.1 and 4.2.2, we regressed the diurnal emission emissions against the cube of the VP product term (in kiloPascals), producing the resulting table:

Table 5

Linear Regression of Diurnal Emissions (Vehicles Failing Only the Purge Test)

Dependent variable is: **Diurnal**

No Selector

R squared = 45.0% R squared (adjusted) = 43.0%
s = 6.140 with 30 - 2 = 28 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	862.12	1	862.12	22.9
Residual	1055.57	28	37.6989	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	2.00177	1.519	1.32	0.1983
Cube of VP_Product / 1,000,000	0.006945	0.0015	4.78	# 0.0001

We then modified the constant term (produced by the regression) so that the resulting curve would pass through the mean of all the relevant data (i.e., all 48 tests on the eight vehicles at nine temperature / RVP combinations). This produced the following equation:

24-Hour Diurnal (grams) = 1.134838 + [0.006945 * Cube of VP_Product] / M **(6)**

Where M = 1,000,000

EPA proposes to use equation **(6)** to estimate the mean 24-hour diurnal emissions of all 1996 and newer model year vehicles that failed only the purge test with the following two modifications (repeated from Sections 4.2.1 and 4.2.2):

1) Regardless of the increase in ambient temperatures, there are no diurnal emissions until the 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 proposes to calculate the diurnal 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 of the predicted value for the ten-degree cycle (with the appropriate RVP) and zero grams.

4.2.4 Diurnal Emissions of "Gross Liquid Leakers"

In a previous 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):

24-Hour Diurnal (grams) = 20.058 + [3.343 * Diurnal_Temperature_Range] **(7)**

EPA proposes to continue using 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 Summary

For the 1996 and newer model year vehicles that were certified to the enhanced evaporative testing procedure, EPA proposes to model the resting loss and diurnal emissions separately for those vehicles having substantial leaks of liquid gasoline. For the non-leakers, EPA proposes to model the resting loss and diurnal emissions separately based on the functional status of the vehicle's evaporative control system.

EPA proposes to model the hourly resting loss emissions (in grams per hour) using the following three formulae:

- For vehicles with substantial leaks of liquid gasoline ("Gross Liquid Leakers"):

  Hourly Resting Loss = 8.84

- For vehicles with properly functioning evaporative control systems:

  Hourly Resting Loss = -0.02786 + [0.000514 * Temperature (°F)] **(1)**

- For vehicles with malfunctioning evaporative control systems:

  Hourly Resting Loss = -0.07654 + [0.001603 * Temperature (°F)] **(2)**

Additionally, any predicted resting loss emission that is negative will be replaced with zero.

EPA proposes to model the full (24-hour) day's diurnal emissions (in grams per day) using the following four formulae:

- For vehicles with substantial leaks of liquid gasoline ("Gross Liquid Leakers"):

  Diurnal = 20.058 + [3.343 * Diurnal_Temperature_Range (°F)] **(7)**

- For vehicles with properly functioning evaporative control systems:

$$\text{Diurnal} = \exp[-0.33599 + (0.002905 * \text{VP\_Product\_Term}) - (0.381496 * \text{RVP})] \quad \textbf{(4)}$$

- For vehicles failing the pressure test:

$$\text{Diurnal} = 7.80475 + [0.012985 * \text{Cube of VP\_Product\_Term}] / M \quad \textbf{(5)}$$

Where M = 1,000,000

- For vehicles failing the purge test:

$$\text{Diurnal} = 1.13484 + [0.006945 * \text{Cube of VP\_Product\_Term}] / M \quad \textbf{(6)}$$

Where M = 1,000,000

Additionally, the following two modifications apply to the diurnal emission that are predicted by any of the four preceding formulae:

1) Regardless of the increase in ambient temperatures, there are <u>no</u> diurnal emissions until the temperature exceeds 40°F.

   For a temperature cycle in which the daily low temperature is below 40°F, EPA proposes to calculate the diurnal 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 of the predicted value for the ten-degree cycle (with the appropriate RVP) and zero grams.

Appendix A

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

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 A (Continued)

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 A (Continued)

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 B

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

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 B (Continued)

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 C

Five 1990-1995 Model Year Vehicles Failing the Pressure Test

Vehicle No.	Fuel RVP	Temp Cycle	VP Product Term	RTD (grams)	Hrly Rst Loss*	Daily Rst Loss	Diurnal (grams)
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 D

Resting Loss Data Used in Regression Analyses
1990-1995 Model Year Vehicles
(By Ambient Temperature)

Category	Veh. No.	60• F	72• F	82• F
Pass Both	**5032**	**0.0043**	**0.0069**	**0.0150**
Pass Both	**5046**	**0.0075**	**0.0097**	**0.0306**
Pass Both	**5047**	**0.0047**	**0.0117**	**0.0150**
Pass Both	**5066**	**-0.0024**	**0.0036**	**0.0071**
Pass Both	**5081**	**0.0052**	**0.0038**	**0.0090**
	Means:	0.0039	0.0071	0.0153
Fail Only Purge	4925	0.0350	0.0608	0.0800
Fail Only Purge	4933	0.1367	0.1867	0.3517
Fail Only Purge	5004	0.0088	0.0203	0.0392
Fail Only Purge	5035	-0.0007	0.0236	0.0031
Fail Only Purge	5040	0.0001	0.0108	-0.0106
Fail Only Purge	5069	-0.0042	0.0101	0.0407
Fail Only Purge	5070	0.0024	0.0052	0.0266
Fail Only Purge	5087	0.0290	0.0000	0.0000
	Means:	0.0259	0.0397	0.0663
Fail Pressure	5008	-0.0102	0.0253	0.0341
Fail Pressure	5021	0.0006	0.0332	0.0155
Fail Pressure	5044	0.0073	0.0088	0.0096
Fail Pressure	5067	0.0324	0.0778	0.0714
	Means:	0.0075	0.0363	0.0327
Fail Either:		0.0198	0.0386	0.0551