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Estimating Weighting Factors for Evaporative Emissions in MOBILE6

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- Draft -

Estimating Weighting Factors for Evaporative Emissions in MOBILE6

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ABSTRACT

In previous documents (M6.EVP.001, M6.EVP.002, and M6.EVP.005), EPA proposed methods of estimating vehicles' resting loss and diurnal emissions based (in part) on the vehicles' performance (pass or fail) on the purge and pressure tests. EPA plans to compute model-year and age specific average resting loss and diurnal emissions by weighting together the emissions of passing and failing vehicles according to their frequency in the in-use fleet. This document describes this approach and EPA's proposed estimates of pass and fail rates as functions of vehicle age.

Please note that EPA is seeking any input from stakeholders and reviewers 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. EPA will then review and consider all comments received and will provide a summary of those comments, and how we are responding to them.

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Estimating Weighting Factors for Evaporative Emissions in MOBILE6

Report Number M6.EVP.006

Larry C. Landman
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1.0 Introduction

In three recently released draft reports [1,2,3]*, the US Environmental Protection Agency (EPA) proposed methods of estimating the resting loss and diurnal emissions from 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. For many of the vehicles used in these studies, the recruitment method was designed to recruit a relatively large number of vehicles that had problems with their evaporative control systems. Specifically, two tests of the integrity of each vehicle's evaporative control system (a pressure test** and a purge test) were used to screen the candidate vehicles. This recruitment bias did not affect the analysis of these data as described in earlier reports; since those analyses were performed within each purge/pressure grouping, the selection was random within the purge/pressure and model year groups. However, to correctly represent the entire in-use fleet the results must be weighted. In this report, EPA proposes weightings for each stratum to estimate the emissions of the entire in-use fleet. EPA will use these factors to weight together the results of the RTD tests, as well as the results of hot soak tests and running loss tests which were also derived from measurements of a stratified sample.

For each of the earlier analyses of resting loss and diurnal data, the sample of test vehicles was divided into four strata. The first of these strata consisted of several vehicles having

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* The numbers in brackets refer to the references in Section 7 (page 36).

** This pressure test was performed by disconnecting the vapor line at the canister and then pressurizing the tank from that position with the gas cap in its normal position. This procedure differs from the method currently being used in Inspection and Maintenance (I/M) lanes.

substantial leaks of liquid gasoline (as opposed to simply vapor leaks); these vehicles were labeled "gross liquid leakers." EPA proposed **[4]** using the following three definitions (based on the evaporative emissions test used) for such vehicles with:

- resting loss emissions (i.e., the mean emissions during the last six hours of the 24-hour RTD test) were at least 2.00 grams per hour (see also reference **[1]**), or

- hot soak test emissions were at least 10.00 grams per test (see also reference **[5]**), or

- running loss test emissions were at least 7.00 grams per mile (see also reference **[6]**).

These three different definitions will identify potentially different sets of vehicles as being "gross liquid leakers" (see Section 3.2). For the remaining three strata, we used the results of the purge and pressure tests to match the stratification of the recruitment process. This approach produces the following three additional strata:

1) vehicles that pass both 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 only the purge test.

This document reports on EPA's proposal to weight those four strata together to obtain estimates (of running loss, hot soak, resting loss, and diurnal emissions) for the entire in-use fleet.

2.0 Data Sources

To develop the appropriate weighting factor for the stratum of vehicles identified as "gross liquid leakers," EPA relied on five groups of data to estimate the frequency of the occurrence of these vehicles (see also reference **[4]**):

- For the "gross liquid leakers" identified by the RTD test, EPA used a sample consisting of 151 vehicles tested by the Coordinating Research Council (CRC) during 1996 as part of its real-time diurnal testing program (Program E-9) combined with 119 vehicles tested by EPA. **[1]**

- For the "gross liquid leakers" identified by the hot soak test, EPA used a sample consisting of 300 vehicles tested

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* Vehicles failing both purge and pressure are discussed in Section 3.1.4.

by Auto/Oil during 1993 as part of its real world hot soak testing program combined with 197 vehicles tested by EPA. [5]

- For the "gross liquid leakers" identified by the running loss test, EPA used a sample consisting of 150 vehicles tested by the CRC during 1997 as part of its running loss testing program (program E-35). **[6]**

- The CRC also tested 50 late-model year vehicles during 1998 as part of its combined hot soak, real-time diurnal, running loss testing program (E-41). **[7]** (These results are used in reference **[4]** to test the predictions of the occurrence of "gross liquid leakers" among newer vehicles.)

- A fifth source of data consisted of the results of a testing program run jointly by the CRC and the American Petroleum Institute (API). **[8]** This program was designed to determine the frequency of vehicles with liquid leaks. Actual measurements of evaporative emissions were not performed in this program; therefore, we cannot determine which of those vehicles identified as having liquid leaks would have actually met any of our definitions of a "gross liquid leaker."

To develop the appropriate weighting factors based on the performance on the purge and pressure tests, EPA used data from an EPA testing contractor, Automotive Testing Laboratories (ATL), which performed purge and pressure tests on a random sample of 13,425 vehicles at its Inspection and Maintenance (I/M) lanes in Indiana and Arizona between the years 1990 and 1995. Since the testing protocols were changing in the early months of the program, we omitted the first nine months of data. We then identified the initial test of each of the test vehicles and calculated, by vehicle age, the number of pre-1996* model year vehicles in each of the three purge/pressure categories.

We combined the results for the I/M lane testing into a single table (Table 1 on page 5). Omitted from all of the columns in Table 1 are the results on approximately fifteen percent of the vehicles for which the purge or pressure tests were not performed. The reasons that testing was not performed varied, and included both periodic problems with the testing equipment as well as problems related to the vehicle (e.g., presence of check-valves or difficulty accessing the necessary lines). All of the subsequent analyses were performed on the sample of vehicles for which the purge/pressure classification could be made. Since all of the subsequent analyses are based on ratios from Table 1 (e.g., the

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***** Limiting the analysis to pre-1996 model year vehicles is related to the phase-in of the enhanced evaporative control vehicles (see Section 4)..

number of classified pressure failures divided by the total number of vehicles that were classifiable), EPA proposes to treat the results of those analyses as if they applied to the entire in-use fleet. This proposal is equivalent to assuming that those 15 percent of unclassifiable vehicles were distributed proportionately among the three purge/pressure strata.

In examining the data in Table 1, we note that there were relatively few vehicles more than 20 years of age. Since small sample sizes tend to result in low statistical confidence in the calculated ratios (i.e., the percent of vehicles at each age that fall into each of the purge/pressure strata), those small sample sizes are an obvious weakness of this analysis. We will address that weakness by using the calculated variances in the ratios to weight the analyses. (That is, the ratios from the model years containing the most vehicles will be counted more heavily than the ratios from the more sparsely sampled model years.)

An alternative approach (not being used) is to smooth the data from the older vehicles by averaging the results from the 66 vehicles over the age of 20 years (all of which were from the industry programs) to obtain a sample with:

- a mean age of 23.23 years,
- 19 vehicles (28.8 percent) passing both the pressure test and the purge test,
- 38 vehicles (57.6 percent) failing the pressure test, and
- 9 vehicles (13.6 percent) failing only the purge test.

That averaged failure rate on the pressure test of almost 60 percent among the vehicles over 20 years of age suggests a substantially higher failure rate among these vehicles than was predicted in MOBILE5 (i.e., under 35 percent). This is due <u>entirely</u> to data recently obtained in the CRC testing programs.

Table 1

Distribution of 14,061 1971-95 Model Year Vehicles

Vehicle Age*	Performance on Purge and Pressure Tests: Fail Pressure	Fail Only Purge	Passing Both	Total
0	5	9	228	242
1	48	29	1,448	1,525
2	42	33	1,302	1,377
3	61	33	1,494	1,588
4	81	42	1,308	1,431
5	94	50	1,475	1,619
6	91	76	1,403	1,570
7	94	74	1,261	1,429
8	88	46	888	1,022
9	68	68	682	818
10	46	44	369	459
11	41	24	192	257
12	64	23	152	239
13	49	20	102	171
14	29	5	62	96
15	19	6	34	59
16	13	3	17	33
17	7	1	7	15
18	4	0	2	6
19	12	1	4	17
20	12	3	7	22
21	3	2	7	12
22	7	0	5	12
23	10	2	3	15
24	6	2	2	10
25	6	3	1	10
26	6	0	1	7

* The quantity "Vehicle Age" is the whole number calculated by subtracting model year from test year and then changing all negative results to zero.

3.0 Analysis

3.1 Modeling Strata Based on Purge and Pressure Tests

Using the data from Table 1, we calculated the rate at which vehicles were present (by age) in the following three categories determined by the results on the pressure test and the purge test.

- vehicles passing both the pressure test and the purge test,
- vehicles failing the pressure test, and
- vehicles failing only the purge test.

These three categories are not independent. Given the results from any two would permit the size of remaining category to be determined. EPA chose to model the rates at which vehicles were present in the first two of those categories. These rates by vehicle age (in years) along with the corresponding 90 percent confidence intervals are given in Tables 2 and 3. The confidence intervals were calculated separately for each vehicle age rather than having an overall calculation for the entire sample. Calculating confidence intervals independently (as if the failure rate at one age were not related to the failure rates of neighboring ages) emphasizes the disparity in the sizes of some of the samples by age, as the size of the confidence interval is substantially controlled by the sample size.

3.1.1 Vehicles Failing the Pressure Test

Calculating (from Table 1) the rates at which vehicles failed the pressure test (regardless of the performance on the purge test) produces the data given in Table 2.

As previously stated, since the 90 percent confidence intervals in Table 2 were calculated separately for each age that was sampled, the confidence intervals are most representative of the relative sample sizes. Rather than immediately attempting to use a regression analysis to obtain an equation relating the rate of vehicle's failing the pressure test to the vehicle's age, we first examined the calculated 90 percent confidence intervals in Table 2.

Table 2

Estimating Rate of Failing the Pressure Test For 14,061 1971-95 Model Year Vehicles With 90 Percent Confidence Intervals

Vehicle Age	Sample Size	Failure Rate	90 Percent Confidence Interval
0	242	2.1%	0.6% - 3.6%
1	1,525	3.1%	2.4% - 3.9%
2	1,377	3.1%	2.3% - 3.8%
3	1,588	3.8%	3.0% - 4.6%
4	1,431	5.7%	4.7% - 6.7%
5	1,619	5.8%	4.8% - 6.8%
6	1,570	5.8%	4.8% - 6.8%
7	1,429	6.6%	5.5% - 7.7%
8	1,022	8.6%	7.2% - 10.1%
9	818	8.3%	6.7% - 9.9%
10	459	10.0%	7.7% - 12.3%
11	257	16.0%	12.2% - 19.7%
12	239	26.8%	22.1% - 31.5%
13	171	28.7%	23.0% - 34.3%
14	96	30.2%	22.5% - 37.9%
15	59	32.2%	22.2% - 42.2%
16	33	39.4%	25.4% - 53.4%
17	15	46.7%	25.5% - 67.9%
18	6	66.7%	35.0% - 98.3%
19	17	70.6%	52.4% - 88.8%
20	22	54.5%	37.1% - 72.0%
21	12	25.0%	4.4% - 45.6%
22	12	58.3%	34.9% - 81.7%
23	15	66.7%	46.6% - 86.7%
24	10	60.0%	34.5% - 85.5%
25	10	60.0%	34.5% - 85.5%
26	7	85.7%	64.0% - 100.0%

Examining the confidence intervals in Table 2, we found that some of those confidence intervals are so large as to be almost useless. (For example, knowing that seven of 15 of the vehicles 17 years of age failed the pressure test indicates that the actual failure is most likely between 25 percent and 68 percent. A range that large is not helpful in predicting the true failure rate.) However, using both the sample failure rates and the confidence intervals, we were able to make the following four observations that were then used to select an appropriate mathematical model:

- The pressure failure rate appears to start (i.e., for new vehicles) between two and four percent.

- The pressure failure rate increases gradually for the first seven years of the vehicle's life.

- The pressure failure rate then increases more rapidly for the next ten years.

- The pressure failure rate then begins to level off (approaching 60 percent, according to the data from the industry programs) (see third "bullet" on page 4).

This type of behavior is typical of a logistic growth function.

Prior to constructing an appropriate logistic growth function, we first "adjusted" the variable "**AGE**" (in Tables 1, 2, and 3) which is based on the test date (since it is the integer calculated by subtracting the model year from the test year). However, since the typical test was performed in early July (mean date of July 3 and median date of July 10), we modified that variable by adding 0.5 so that the predicted rate of vehicles failing the pressure test would be based on the age of the vehicles as of the first of January which coincides with the date used in MOBILE.

To account for differences in the size of the confidence intervals (or, equivalently the sample size) the data were weighted by the reciprocal of the variance. The "logistic growth" function that best models the weighted pressure test failure rates from Table 2 is given by the following equation:

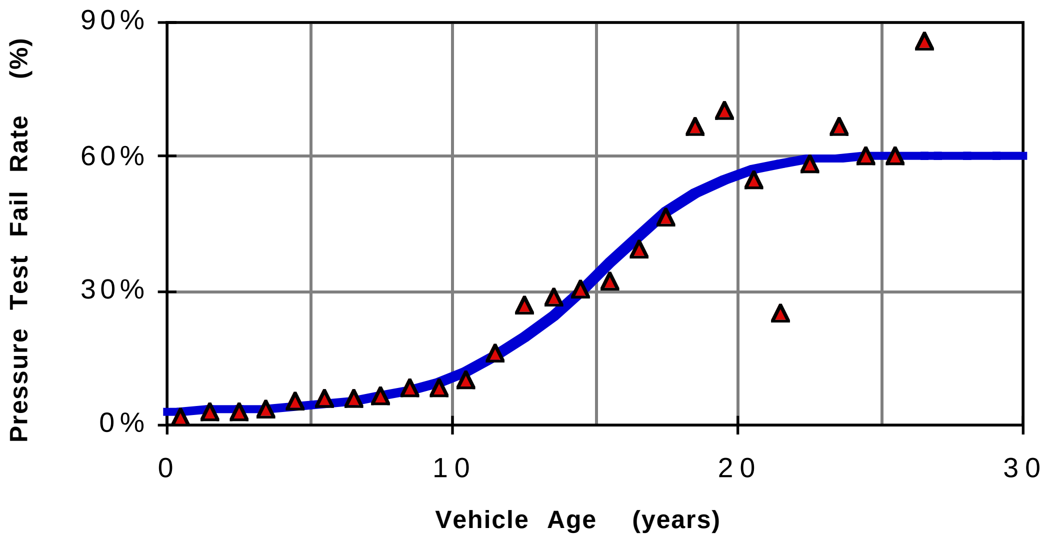
$$\textbf{Pressure Failure Rate} = \frac{0.6045}{1 + 17.733*\exp[-0.01362*(AGE^{\wedge}2)]} \qquad (1)$$

Estimates based on this equation of failure rates on the pressure test are given in Appendix A. These estimates must be adjusted for the "gross liquid leakers" (see Section 3.3).

In Figure 1 (on the following page), we plotted both the measured failure rate on the pressure test (from Table 2, shifted by six months to compensate for the July testing) and the curve described by equation **(1)**. That graph suggests that equation **(1)** is a very good fit for the measured failure rates except at ages 18, 19 and 21 years (for which fewer than 20 vehicles were recruited at each age). Also, for vehicles over 20 years of age, the predicted failure rate on the pressure test is close to 60 percent which closely approximates the results of those 66 tests from industry programs (see third "bullet" on page 4).

Figure 1

Comparison of Measured and Predicted Rates
For Vehicles Failing the Pressure Test
(by vehicle age)



3.1.2 Vehicles Passing Both the Pressure and the Purge Tests

As described in the preceding section, we first calculated from Table 1 the rates at which vehicles passed both the pressure and the purge tests, yielding the results given in Table 3.

As in the case of the failure rate on the pressure test, we were able to make the following four observations from Table 3:

- The rate at which vehicles passed both the pressure test and the purge test starts (i.e., for new vehicles) between 92 and 96 percent.

- The rate at which vehicles passed both the pressure test and the purge test decreases gradually for the first seven years of the vehicle's life.

- The rate at which vehicles passed both the pressure test and the purge test then decreases more rapidly for the next ten years.

- The rate at which vehicles passed both the pressure test and the purge test then begins to level off (approaching 20 to 40 percent, according to the data from the industry programs) (see second "bullet" on page 4).

Table 3

Estimating Rate of Passing Both the Pressure and Purge Tests For 14,061 1971-95 Model Year Vehicles With 90 Percent Confidence Intervals

Vehicle Age	Sample Size	Rate	90 Percent Confidence Interval
0	242	94.2%	91.7% - 96.7%
1	1,525	95.0%	94.0% - 95.9%
2	1,377	94.6%	93.5% - 95.6%
3	1,588	94.1%	93.1% - 95.1%
4	1,431	91.4%	90.2% - 92.6%
5	1,619	91.1%	89.9% - 92.3%
6	1,570	89.4%	88.1% - 90.6%
7	1,429	88.2%	86.8% - 89.6%
8	1,022	86.9%	85.2% - 88.6%
9	818	83.4%	81.2% - 85.5%
10	459	80.4%	77.3% - 83.4%
11	257	74.7%	70.2% - 79.2%
12	239	63.6%	58.5% - 68.7%
13	171	59.6%	53.5% - 65.8%
14	96	64.6%	56.6% - 72.6%
15	59	57.6%	47.0% - 68.2%
16	33	51.5%	37.2% - 65.8%
17	15	46.7%	25.5% - 67.9%
18	6	33.3%	1.7% - 65.0%
19	17	23.5%	6.6% - 40.5%
20	22	31.8%	15.5% - 48.2%
21	12	58.3%	34.9% - 81.7%
22	12	41.7%	18.3% - 65.1%
23	15	20.0%	3.0% - 37.0%
24	10	20.0%	0.0% - 40.8%
25	10	10.0%	0.0% - 25.6%
26	7	14.3%	0.0% - 36.0%

As before, the "logistic growth" function appeared to be the best choice for modeling the rates at which vehicles passed both the pressure and the purge tests. After adjusting for age, the resulting equation is given below as equation **(2)**:

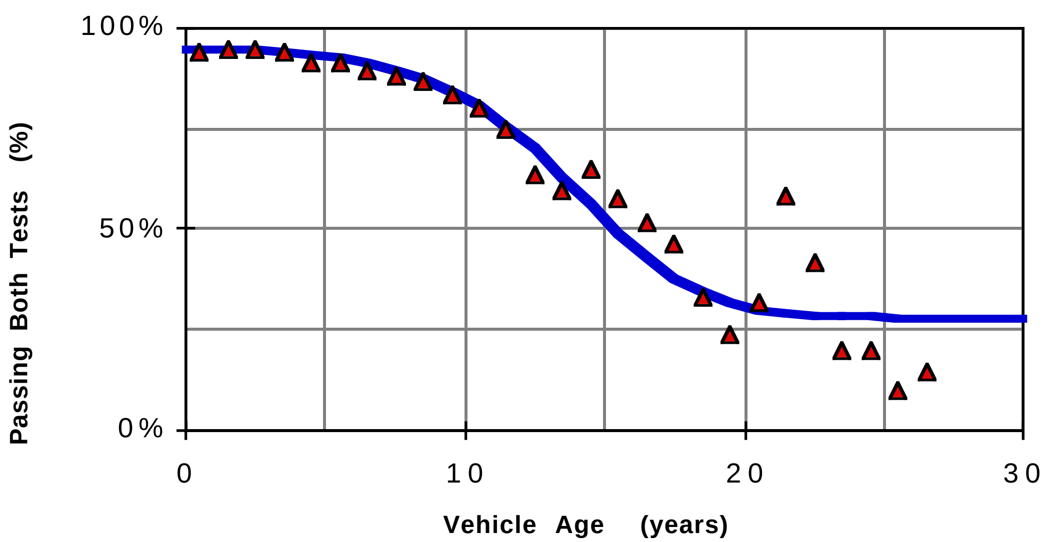
$$\text{Rate of Passing Both} = 1 - \frac{0.7200}{1 + 13.40*\exp[-0.0145*(AGE^2)]} \qquad (2)$$

Estimates based on equation **(2)** of the rates of vehicles passing both the purge and pressure tests are given in Appendix A. These estimates must be adjusted for the "gross liquid leakers" (see Section 3.3).

In Figure 2, for vehicles passing both the purge and pressure tests, we plotted both the measured rates (from Table 2, with age shifted by six months to compensate for the July testing) and the curve described by equation **(2)**. That graph suggests that equation **(2)** is a very good fit for the measured rates for ages at which at least 20 vehicles were sampled. Also, for vehicles over 20 years of age, the predicted rate of vehicles passing both the purge and pressure tests is close to 29 percent which closely approximates the results of those 66 tests from industry programs (see second "bullet" on page 4).

Figure 2

Comparison of Measured and Predicted Rates
For Vehicles Passing Both the Purge and Pressure Tests
(by vehicle age)



3.1.3 Vehicles Failing ONLY the Purge Test

The third (and final) stratum based on vehicles' performance on the purge and pressure tests is that containing vehicles that failed only the purge test. EPA proposes to estimate that stratum by subtracting from one hundred percent the total of equation **(1)** plus equation **(2)** (prior to adjusting for the gross liquid leakers, as discussed in Section 3.3). Since, for some vehicle ages, the rate of decline in equation **(2)** is greater that the rate of growth in equation **(1)**, this approach has the effect of predicting a decrease in the rate of purge only failures for vehicles older than 16 years of age. (This effect suggests that some of the vehicles that had failed only the purge test would begin to also fail the pressure test, thus migrating into the pressure failure stratum.)

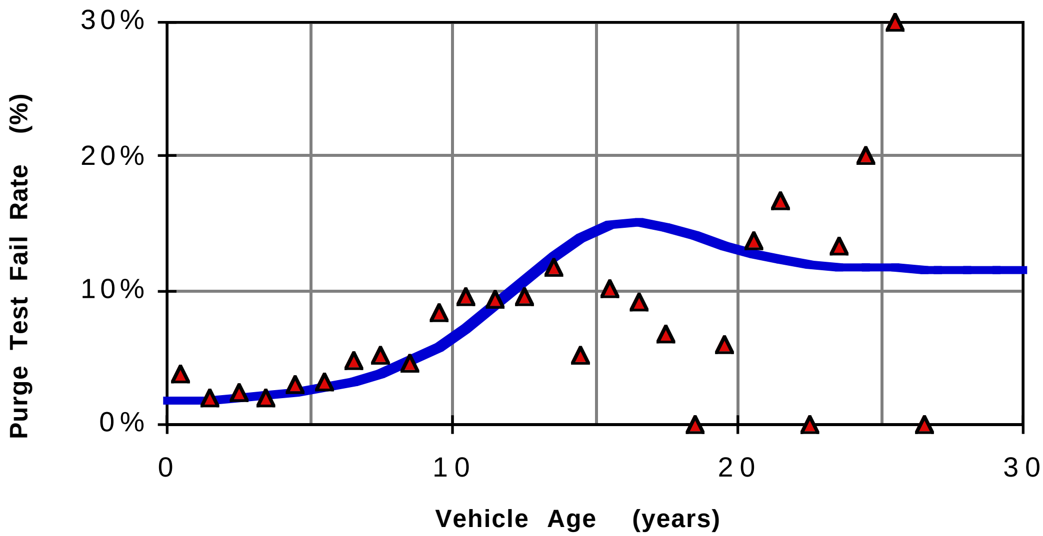
This effect is illustrated in Figure 3. If we combine this estimate of the incidence of vehicles' failing only the purge test with the estimate (from Section 3.1.4) of failing both the purge and pressure tests, we obtain a predicted failure rate on the purge test (regardless of any pressure test result). This purge test failure rate does not exhibit that quirk of a decrease in failure rate with increasing age.

The predicted size (in percent) of the stratum of vehicles that failed only the purge test is given in Appendix A. These estimates must be adjusted for the "gross liquid leakers" (see Section 3.3).

In Figure 3, for vehicles failing only the purge test, we plotted both the measured rates (calculated from Table 1 and shifted by six months to compensate for July testing) and the curve described by subtracting from one hundred percent the total of equation **(1)** plus equation **(2)**.

Figure 3

Comparison of Measured and Predicted Rates For Vehicles Failing ONLY the Purge Test (by vehicle age)



The preceding graph indicates that the combination of equations **(1)** and **(2)** is a very good fit for the measured rates for ages at which at least 100 vehicles were sampled (i.e., through age 13).

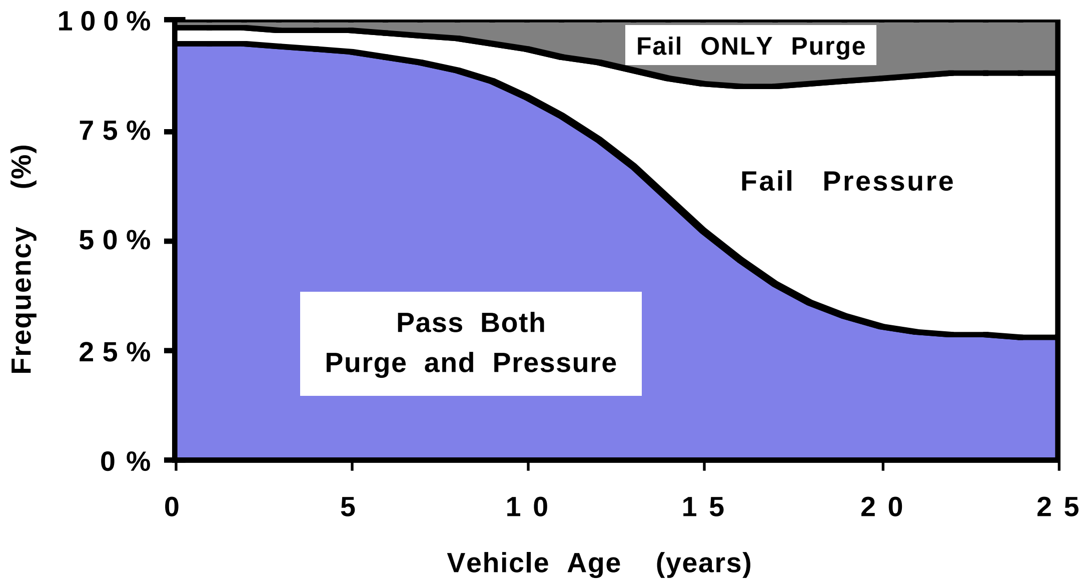
Also, for vehicles over 20 years of age, the predicted rate of vehicles failing only the purge test is close to 12 percent which closely approximates the results of those 66 tests from industry programs (see fourth "bullet" on page 4).

3.1.4 Summary of Purge and the Pressure Failure Rates

Combining the predicted rates from Figures 1, 2, and 3 (or Appendix A) into a single area graph produces the following:

Figure 4

Predicted Pressure and Purge Rates
(by vehicle age)



3.1.5 Vehicles Failing Both the Purge and the Pressure Tests

When EPA analyzed the RTD data, it was determined that there were insufficient test results to distinguish between the diurnal emissions of vehicles that failed both the purge and pressure tests from those that failed only the pressure test. Therefore, those vehicles were combined into the single stratum of vehicles that failed the pressure test (regardless of their performance on the purge test). Since the purpose of this study is to develop factors to weight together the estimates of the individual stratum to predict the in-use fleet emissions, it was not necessary to model frequency of the stratum of vehicles that failed both the purge and pressure tests.

As a service to possible future researchers and modelers who may require an estimate of the number of vehicles failing both the purge and pressure tests (and based on the same sample that produced equations (1) and (2)), EPA performed the following analysis.

The approach was similar to the one used in Sections 3.1.1 and 3.1.2 in which a table containing the frequencies with the corresponding ninety percent confidence intervals was created (see Table 4).

Table 4

Estimating Rate of Failing BOTH the Pressure and Purge Tests For 1971-95 Model Year Vehicles With 90 Percent Confidence Intervals

Vehicle Age	Sample Size	Rate	90 Percent Confidence Interval
0	242	0.0%	0.0% - 0.5%
1	1,522	0.2%	0.0% - 0.4%
2	1,377	0.0%	0.0% - 0.2%
3	1,587	0.3%	0.0% - 0.5%
4	1,430	0.8%	0.4% - 1.1%
5	1,619	0.4%	0.1% - 0.6%
6	1,568	0.6%	0.3% - 0.9%
7	1,428	0.8%	0.4% - 1.2%
8	1,020	1.3%	0.7% - 1.9%
9	814	1.5%	0.8% - 2.2%
10	458	2.6%	1.4% - 3.8%
11	254	2.8%	1.1% - 4.4%
12	235	6.0%	3.4% - 8.5%
13	169	7.1%	3.9% - 10.4%
14	94	7.4%	3.0% - 11.9%
15	58	6.9%	1.4% - 12.4%
16	33	15.2%	4.9% - 25.4%
17	15	26.7%	7.9% - 45.4%
18	6	0.0%	0.0% - 28.5%
19	17	23.5%	6.6% - 40.5%
20	22	4.5%	0.0% - 11.9%
21	12	0.0%	0.0% - 17.7%
22	12	16.7%	0.0% - 34.4%
23	15	53.3%	32.1% - 74.5%
24	10	30.0%	6.2% - 53.8%
25	10	30.0%	6.2% - 53.8%
26	7	57.1%	26.4% - 87.9%

As the reader may note, some of the sample sizes in Table 4 do not match the supposedly same samples in the first three tables. In the first three tables, vehicles that failed the pressure test but did not have a successful purge test were included in the stratum "fail pressure" and, thus, included in the total as well. However, those same vehicles would not be included in Table 4.

After adjusting for age, the "logistic growth" function that best models the frequency of vehicle's failing both the pressure and purge tests from Table 4 is given by the following equation:

$$\text{Rate of Failing Both} = \frac{0.3536}{1 + 414.96*\exp[-0.32955*AGE]} \qquad (3)$$

In Figure 5, for vehicles failing both the purge and pressure tests, we plotted both the measured rates (from Table 4, shifted by six months to compensate for the July testing) and the curve described by equation **(3)**.

Figure 5

Comparison of Measured and Predicted Rates
For Vehicles Failing Both the Pressure and Purge Tests
(by vehicle age)

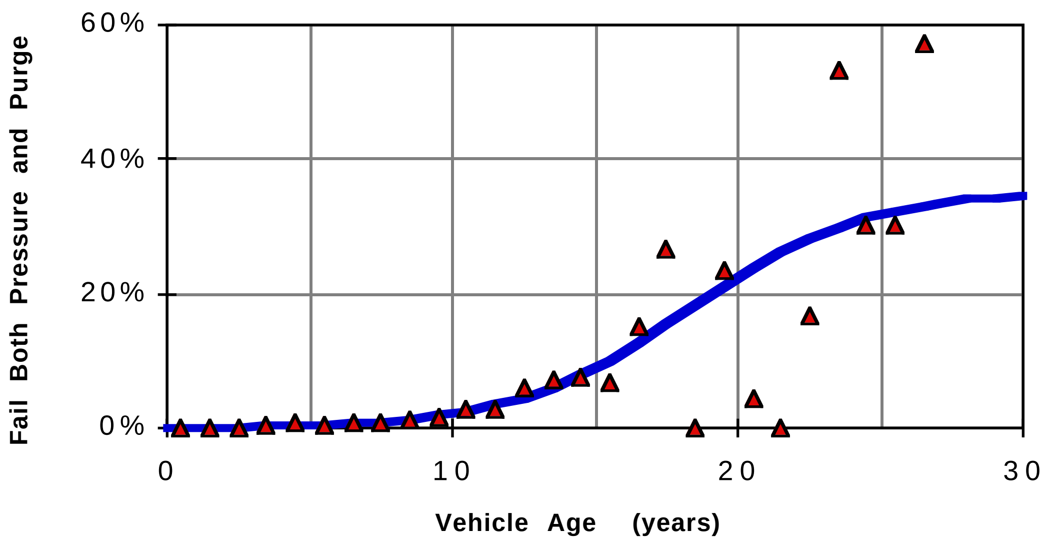


Figure 5 suggests that equation **(3)** is a very good fit for the measured rates for ages at which at least 30 vehicles were sampled (i.e., through age 16). Also, for the vehicles over 20 years of age, the data in Table 4 indicates that 20 out of 66 (30.3%) of those vehicles over 20 years of age (with a mean age of 23.2

years) failed both the purge and pressure tests, and equation **(3)** predicts that the failure rate would be 29.5 percent. Thus, equation **(3)** is also a very good fit for the measured rates for the older vehicles.

3.2 Modeling the Stratum of "Gross Liquid Leakers"

The set of vehicles identified as "gross liquid leakers" varies depending upon which type of evaporative emission is being considered. Earlier (see "bulletted" points on page 2), we presented three definitions each based on one type of test (i.e., RTD test, hot soak test, and running loss test). These definitions were developed in a recent report devoted exclusively to the subject of "gross liquid leakers" **[4]**. In that report, EPA produced the following two equations to predict the frequency of "gross liquid leakers" occurring on the RTD and on the running loss tests for evaporative emissions:

$$\text{Rate of Gross Liquid Leakers Based on RTD Testing} = \frac{0.08902}{1 + 414.613 * \exp[-0.3684 * AGE]} \quad (4)$$

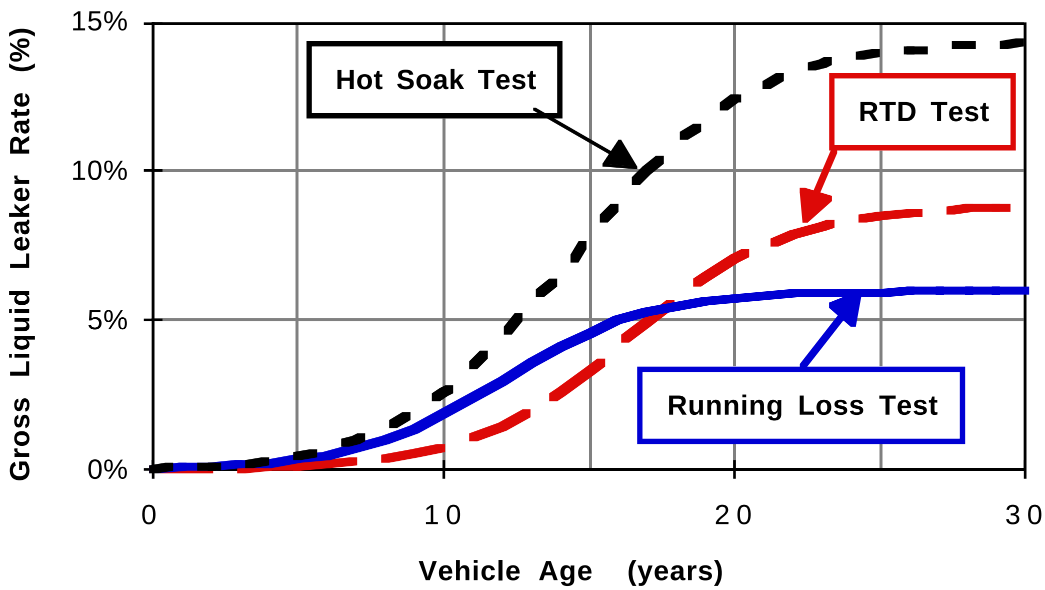
$$\text{Rate of Gross Liquid Leakers Based on Running Loss Testing} = \frac{0.06}{1 + 120 * \exp[-0.4 * AGE]} \quad (5)$$

See reference **[4]** for the details of how these equations were derived.

In that same report, EPA proposed that the vehicles classified as "gross liquid leakers" on the hot soak test are the same vehicles identified as gross liquid leakers on either the running loss or RTD tests. (That is, the set of vehicles classified as gross liquid leakers on the hot soak test is the union of the set of vehicles classified as gross liquid leakers on the RTD test with the set of vehicles classified as gross liquid leakers on the running loss test.) Therefore, the rate of gross liquid leakers as identified on the hot soak test would be the sum of the two rates for the RTD testing and the running loss testing minus the number of double counted vehicles (i.e., the product of those two rates assuming these two categories are independent of each other). Using equations **(4)** and **(5)** plus the preceding assumption, the predicted rates of "gross liquid leakers" were calculated (for each of the three test types) and are plotted in Figure 6 (on the following page) and appear in Appendix B.

Figure 6

**Predicted Occurrences of "Gross Liquid Leakers"
On Each of Three Tests of Evaporative Emissions
(by vehicle age)**



It is important to note that this model of the frequency of gross liquid leakers is based on the assumption that modern technology vehicles will show the same tendency toward gross liquid leaks as do the older technology vehicles at the same age. However, if the modern technology vehicles were to exhibit a lower tendency to leak (due to the more stringent demands imposed by the new evaporative emissions certification procedure as well as heightened attention to safety, e.g., fuel tank protection and elimination of fuel line leaks), the effect would be to replace each of the three logistic growth functions with two or three curves specific to different model year groups.

Since EPA has no data to indicate model-year specific rates, EPA proposes to use the model illustrated in Figure 6, to estimate the occurrence in the in-use fleet of these vehicles that have substantial leaks of liquid gasoline (i.e., "gross liquid leakers") for vehicles that were <u>not</u> designed to meet the new enhanced evaporative test procedure (i.e., vehicles up through the 1996 model year along with some of the 1997 and 1998 model years). For the vehicles designed to meet the new enhanced evaporative test procedure, EPA proposes to modify that equation (see Section 4.0).

3.3 Combining Purge/Pressure Rates with Gross Liquid Leaker Rates

In Section 3.1 we characterized the three strata resulting from the individual vehicle's performance on the purge and pressure tests. In Section 3.2, we characterized the additional stratum created for the "gross liquid leakers." In order to make these strata non-overlapping (i.e., mutually exclusive), we must remove the "gross liquid leakers" from the other three strata.

To determine the distribution of the gross liquid leakers among the other three strata, we examined the 270 vehicles in the combined EPA/CRC RTD testing programs. Seven vehicles were identified as "gross liquid leakers" out of those 270 vehicles that were tested. Of these seven gross liquid leakers:

- four had failed both the purge and pressure tests,
- two had failed only the pressure test, and
- one had passed both the purge and pressure tests.

This distribution of seven gross liquid leakers proves that gross liquid leakers can and do occur within the all three of the purge/pressure strata. EPA proposes to first estimate the number of gross liquid leakers within each of the purge/pressure strata and then to remove them to form a fourth stratum consisting of only the gross liquid leakers. Rather than attempting to estimate the distribution of all gross liquid leakers based on a sample of only seven vehicles, EPA proposes that MOBILE6 will simply distribute the liquid leakers proportionately among the three purge/pressure categories.

For example, if we were to take a hypothetical fleet of 10,000,000 vehicles 10 years of age, then Appendix B predicts that 780,000 (7.8 percent) of them will be "gross liquid leakers" on the RTD test. Similarly, Appendix A indicates that 10,910,000 (10.91 percent) will fail the pressure test, 647,000 (6.47 percent) will fail only the purge test, and the remaining 8,262,000 (82.62 percent) will pass both tests. Distributing those 780,000 "gross liquid leakers" proportionately among the three purge/pressure strata predicts the following distribution:

Table 5

Predicted Distribution on RTD Test

Purge/Pressure Strata	"Gross Liquid Leakers"	Not "Gross Liquid Leakers"	TOTALS
Fail Pressure	85,098	1,005,902	1,091,000
Fail ONLY Purge	50,466	596,534	647,000
Pass Both	644,436	7,617,564	8,262,000
TOTALS	780,000	9,220,000	10,000,000

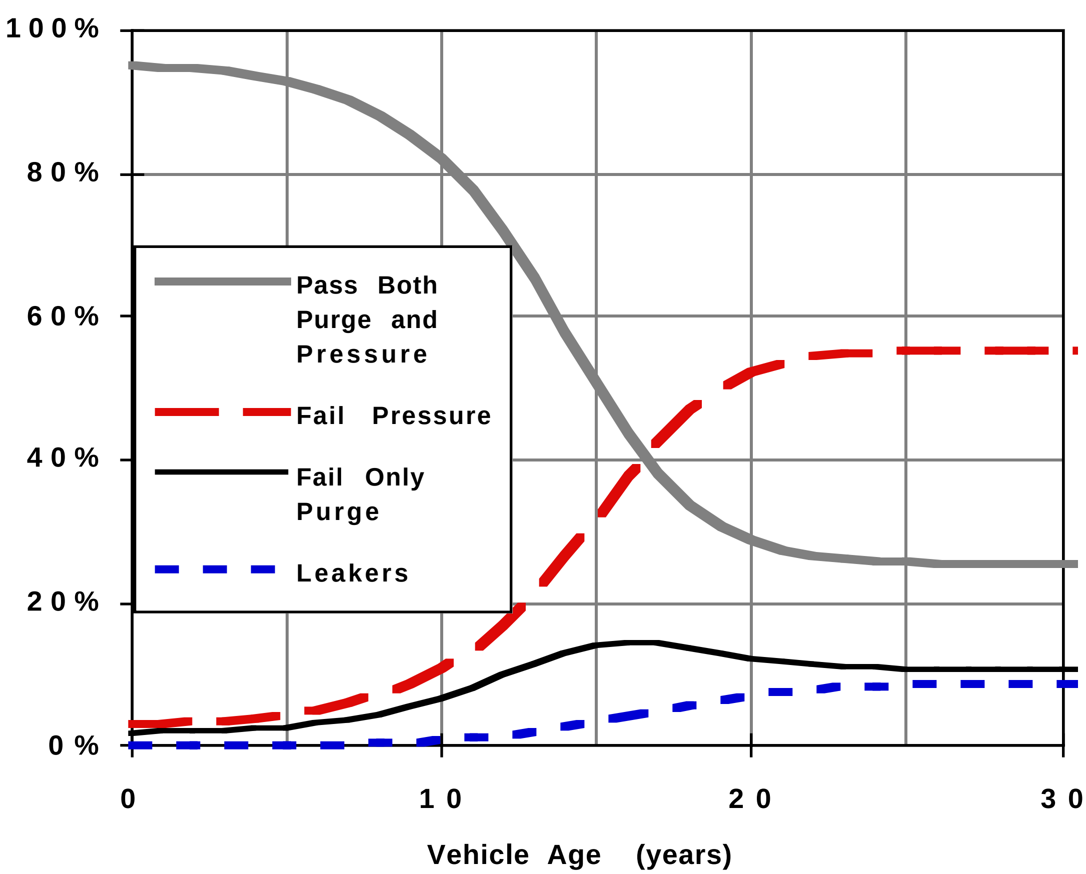
Thus, Table 5 indicates that for 10 year old vehicles on the RTD test:

- 7.80 percent of those vehicles will be "gross liquid leakers" on a RTD test,
- 10.06 percent of those vehicles will fail the pressure test, but will not be "gross liquid leakers,"
- 5.97 percent of those vehicles will fail only the purge test, but will not be "gross liquid leakers," and
- 76.18 percent of those vehicles will pass both the pressure and purge tests, and will not be "gross liquid leakers."

Repeating this process for each vehicle age in Appendices A and B produces the estimated size of each of the four strata for the RTD test for each age. The results are plotted below:

Figure 7

Predicted Strata Sizes on RTD Test
(by vehicle age)



Repeating this process using the "running loss" and "hot soak" columns from Appendix B will produce the estimates of the size of the four strata for use with each of those two types of evaporative emissions.

4.0 Modeling Enhanced EVAP Vehicles Equipped with OBD

Beginning with the 1996 model year, manufacturers were required to certify twenty percent of their vehicles using a new "enhanced" evaporative testing procedure and to equip those vehicles with an on-board diagnostic (OBD) system that would detect pressure leaks and malfunctions in the purge system; that percentage is scheduled to increase to one hundred percent by the 1999 model year. The phase-in percentages are prescribed in 40 CFR 86.096-8 and shown below in Table 6.

Table 6

Phase-In of Vehicles with Enhanced Evaporative Controls

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

To predict the performance of these 1996 and newer vehicles on the purge and pressure tests, the effects of two factors must be considered:

1) A change in the regulations requires a doubling of the period during which these vehicles must meet the evaporative emissions standards (increased from 50,000 to 100,000 miles for light-duty vehicles).
2) The OBD system is expected to alert each vehicle's owner (or driver) to most problems with the evaporative control system, thus permitting the owner to decide whether to repair the problem.

In order to meet the increased durability and more stringent 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 proposed in a separate report (M6.EVP.005) to use a separate set of estimates of both resting loss and diurnal emissions for these vehicles. However, EPA does not have actual data on the effects of these changes in durability that translates into changes in the purge and pressure failure rates estimated in Section 3.1 for the pre-1996 model year vehicles.

EPA, therefore, proposes to use the doubling in the durability requirement to modify equations **(1)**, **(2)**, **(4)**, and **(5)** (from Sections 3.1.1, 3.1.2, and 3.2) by replacing the variable "**AGE**" with "**AGE/2**" resulting in:

Pressure Failure Rate of Enhanced Evaporative Control Vehicles

$$= \frac{0.6045}{1 + 17.733*\exp[-0.003405*(AGE^2)]} \qquad (6)$$

Rate of Passing Both for Enhanced Evaporative Control Vehicles

$$= 1 - \frac{0.7200}{1 + 13.40*\exp[-0.003625*(AGE^2)]} \qquad (7)$$

Rate of Gross Liquid Leakers on the RTD Test for the Enhanced Evaporative Control Vehicles

$$= \frac{0.08902}{1 + 414.613*\exp(-0.1842*AGE)} \qquad (8)$$

Rate of Gross Liquid Leakers on the Running Loss Test for the Enhanced Evaporative Control Vehicles

$$= \frac{0.06}{1 + 120*\exp[-0.2 * AGE]} \qquad (9)$$

Using these equations, we generated the estimated failure rates in Appendix C for those (1996 and newer) vehicles certified to the enhanced evaporative control standards. These estimates assume only the benefits of changes in durability, with no estimation of the effect from the OBD system.

Since the OBD system is designed to alert each vehicle's owner to problems with the evaporative control system. The appearance of a warning light should result in at least some owners having their malfunctioning vehicles repaired. Thus, the OBD system has the potential to affect the relative sizes of the purge/pressure strata (in Appendix C), depending both on its ability to identify problems in the evaporative control systems and on the owners inclination to repair such problems.

In an separate analysis (M6.IM.001) of exhaust (not evaporative) emissions, EPA proposed that the effect of an OBD system will vary, based on the vehicle's warranty and the presence of an I/M program. That proposal stated that:

- The vehicle's malfunction indicator light (MIL) would detect/identify 85 percent of the instances of the vehicle's exceeding twice the <u>exhaust</u> emission standard.
- While the vehicle is under its full ("bumper to bumper") warranty (i.e., up through 36,000 miles), 90 percent of the owners will have the vehicle repaired when the MIL indicates a problem.
- When the warranty covers only the electronic control module and the catalytic converter (i.e., from 36,000 through 80,000 miles), only 10 percent of the owners will have the vehicle repaired when the MIL indicates a problem. That percentage would increase from 10 to 90 percent if that geographic area has an I/M program that requires the MIL to indicate that there are no problems.
- When the vehicle is no longer covered by a manufacturer's warranty (i.e., over 80,000 miles), none (i.e., zero percent) of the owners will have the vehicle repaired when the MIL indicates a problem. That percentage will increase from zero to 90 percent if that geographic area has an I/M program that requires the MIL to indicate that there are no problems.

EPA proposes to adapt those assumptions (modified slightly) for evaporative emissions. Specifically:

- The vehicle's malfunction indicator light (MIL) would detect/identify 85 percent of the instances of the vehicle's failing the purge test or failing the pressure test. (It is assumed that the OBD system would <u>not</u> detect the presence of a gross liquid leak.)

- While the vehicle is within its full warranty period (i.e., approximately through the age of three years), 90 percent of the owners will have the vehicle repaired when the MIL indicates a problem. (These first two assumptions suggest that the OBD system combined with the manufacturer's warranty program will reduce the incidence of vehicles failing either the pressure or purge tests by 76.5 percent.)

- While the vehicle is under its partial warranty period (i.e., approximately ages four through six years), only 10 percent of the owners will have the vehicle repaired when the MIL indicates a problem. (This assumption suggests that the OBD system combined with the manufacturer's warranty program will reduce the incidence of vehicles that in their fourth, fifth, or sixth years newly fail either the purge or pressure tests.) That percentage would increase from 10 to 90 percent if that geographic area were to have an I/M program requiring the MIL to indicate that there are no problems.

- When the vehicle's evaporative control system is no longer covered by a manufacturer's warranty (i.e., beyond about six years of age), none (i.e., zero percent) of the owners will have the vehicle repaired when the MIL indicates a problem. That percentage would increase from zero to 90 percent if that geographic area were to have an I/M program requiring the MIL to indicate that there are no problems.

Note: EPA is currently studying in-use OBD systems. The assumptions listed here are working assumptions and subject to change.

Applying these assumptions to the strata sizes in Appendix C produces the tables in Appendices D and E that cover the 1999 and later model year vehicles, for the I/M and non-I/M areas respectively.

For the vehicles produced during the phase-in years of the enhanced evaporative standard (i.e., model years 1996 through 1998), EPA proposes to use a three-step approach:

- First, the fraction of the fleet <u>not</u> manufactured to the new enhanced evaporative standard will be treated the same as the 1986-95 model year vehicles. That is, the emissions for each of the four purge/pressure/leaker strata will be calculated and then weighted together (using Appendix A) for each of the three years (1996-1998).

- Then, for the vehicles manufactured to the new enhanced evaporative standard, we will calculate the predicted emissions for each of the four purge/pressure/leaker strata, and then weight them together using the rates in either Appendix D (I/M area) or Appendix E (non-I/M area).

- Finally, we will weight those two sets of results together using the phase-in percentages in Table 6.

5.0 Comparisons with MOBILE5

5.1 Comparisons of Weighting Factors

Both the MOBILE5 model and this proposal weight the estimated evaporative emissions based on each vehicle's performance on purge and pressure tests; however there are several structural differences:

- The weighting factors in MOBILE5 are each functions of a continuous variable (i.e., each model year's average odometer) while the weighting factors in this proposal are functions of a discrete variable (i.e., each model year's estimated age).

- The weighting factors in this proposal are smooth functions (i.e., exponential) of the estimated age. Although the weighting factors in MOBILE5 are continuous, they are not smooth functions (they are piece-wise linear).

- MOBILE5 does not have a separate stratum for the vehicles classified as "gross liquid leakers" while this proposal does. We will, therefore, compare the MOBILE5 weighting factors with the unadjusted factors from Section 3.1 of this report.

The comparisons between the MOBILE5 weighting factors for light-duty vehicles for each of the three purge/pressure strata and the weighting factors in this proposal are illustrated in the following three figures:

- Figure 8 compares the estimates of vehicles passing both the purge test and the pressure test. (Subtracting each of those estimates from 100 percent will yield the associated rates of vehicles failing either the purge test, or the pressure test, or both tests.)

- Figure 9 compares the estimates of vehicles failing the pressure test (regardless of the performance on the purge test).

- Figure 10 compares the estimates of vehicles failing only the purge test.

Figure 8

Comparison of Predictions for Frequency of Vehicles
Passing Both the Purge and Pressure Tests
(by vehicle age)

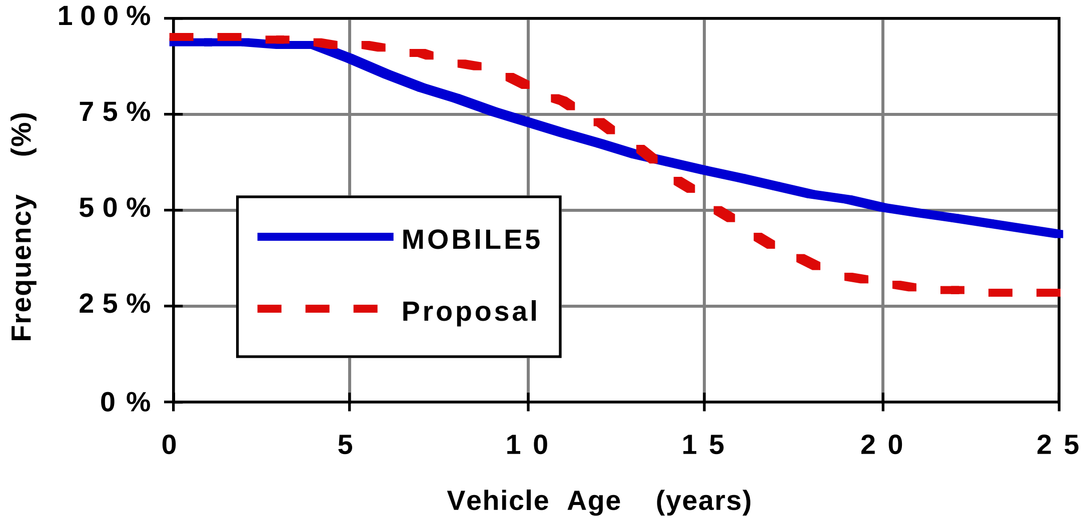


Figure 9

Comparison of Predictions for Frequency of Vehicles
Failing the Pressure Test
(by vehicle age)

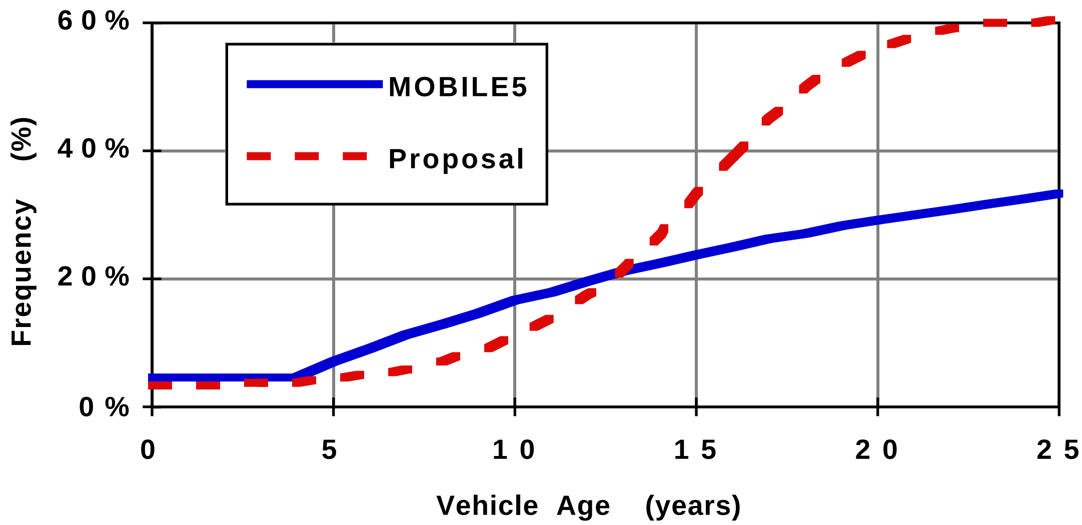
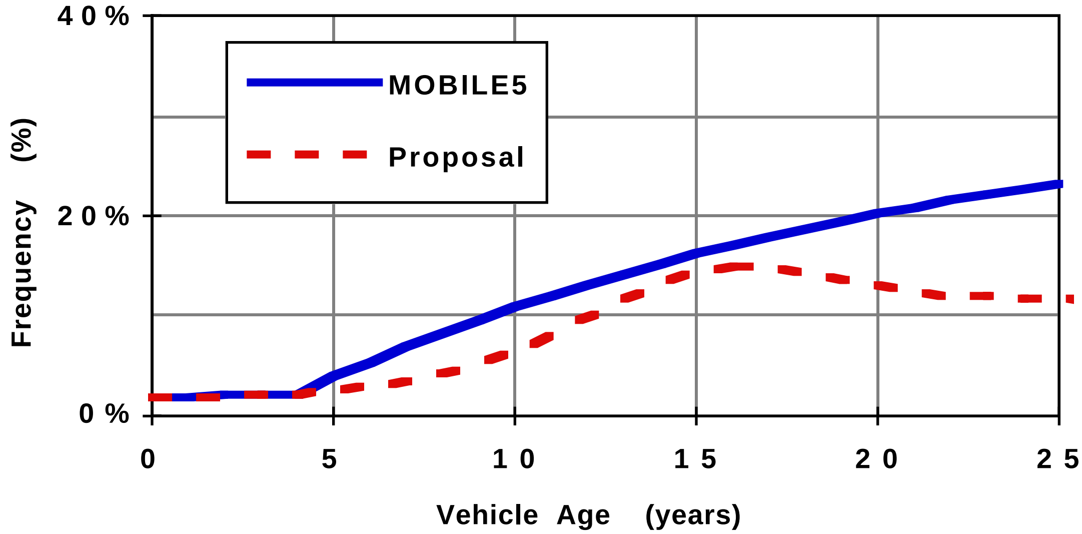


Figure 10

Comparison of Predictions for Frequency of Vehicles Failing ONLY the Purge Test (by vehicle age)



Based on examinations of these three graphs, we can make the following observations:

- The most obvious difference between the weighting factors used in MOBILE5 and those being proposed in this report is that the factors proposed in this report are capped (around age 20) while the MOBILE5 factors are not.

- Despite the structural differences (i.e., smooth function of a discrete variable versus piece-wise linear function of a continuous variable) between these two sets of weighting factors, they produce similar results for vehicles up to about 12 to 13 years of age.

- The estimates being proposed in this report predict substantially a higher proportion of vehicles failing the pressure test for vehicles older than 13 years of age than does the MOBILE5 model.

5.2 Comparisons of Weighted Diurnal Emissions

By combining the information in this report with the information in earlier reports, we can estimate the diurnal emissions for the in-use fleet.* To compare these proposed estimates with those predicted by the MOBILE5 model, the MOBILE5 model was run for a fleet with a national distribution of model years (as of January 1, 1995) with two likely combinations of temperature cycle and fuel RVP (assuming no weathering of the fuel):

- daily temperatures cycling between 60 and 84 degrees Fahrenheit using fuel with a 9.0 RVP (see Figure 11) and
- daily temperatures cycling between 82 and 106 degrees Fahrenheit using fuel with a 7.0 RVP (see Figure 12).

Each MOBILE5 run generates estimated diurnal emissions for the 25 most recent model years, which for these runs were the 1971 through 1995 model years.

In Figures 11 and 12, the typical (i.e., mean) 24-hour diurnal emissions for each vehicle are plotted against model year. Visual inspections of Figures 11 and 12 suggest that the estimates of diurnal emissions resulting from this new proposal (for each of those two combinations of fuel RVP and temperature cycle) for each model year are:

- close (within a gram per vehicle per day) to MOBILE5 estimates for the 1986 to 1995 model year vehicles,
- typically 25 to 75 percent higher (for 9.0 and 7.0 RVP fuels, respectively) than MOBILE5 estimates for 1980 to 1985 model year vehicles, and
- typically 30 to 40 percent higher than MOBILE5 estimates for 1972 to 1979 model year vehicles.

In these two examples the variable **MODEL YEAR** can be transformed into **AGE** using the equation: **AGE = 95 - (MODEL YEAR).**

***** It is important to note that these (following) proposed estimates are only of the full one-day diurnal emissions. They do include diurnal emissions from "gross liquid leakers." But, they do <u>not</u> include evaporative emissions from interrupted (i.e., partial-day) diurnals, nor from multi-day diurnals, nor from running loss, nor from hot soaks. Estimates of these excluded sources are being developed. A true comparison between this proposal and MOBILE5 will require using activity data to weight together all of these individual components of evaporative emissions.

Figure 11

Comparison of Predictions for In-Use Diurnal Emissions by Model Year
60° to 84° F Cycle -- Using 9.0 RVP Fuel
(As of January 1, 1995)

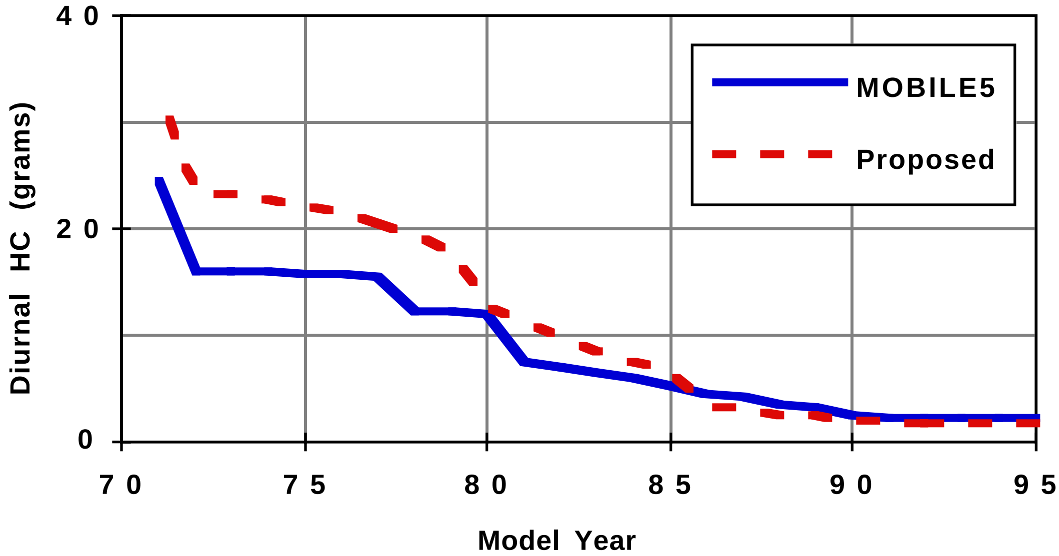
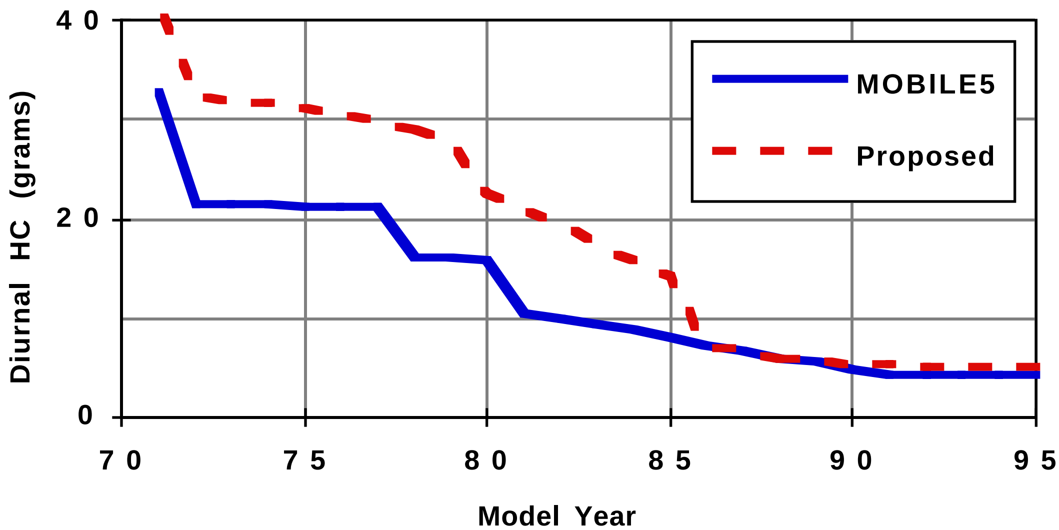


Figure 12

Comparison of Predictions for In-Use Diurnal Emissions by Model Year
82° to 106° F Cycle -- Using 7.0 RVP Fuel
(As of January 1, 1995)



A similar comparison for the vehicles certified to the new enhanced evaporative emission requirements (i.e., 1999 and newer vehicles, along with some 1996-98 model year vehicles) is provided in Section 5.3.

In Figures 11 and 12, we weighted each model year's estimated diurnal emissions by the relative number of vehicles in the fleet, we obtain the estimate of the mean daily diurnal emissions for an average in-use vehicle subject to a full day's diurnal:

Temperature Cycle and Fuel	MOBILE5 Estimate	New Proposal
60° to 84° F with 9.0 RVP	4.86	5.42
82° to 106° F with 7.0 RVP	7.61	10.86

We repeated these calculations for several dozen combinations of fuel RVP and temperature cycles and then graphed the resulting averages in Figures 13 through 16. The first three figures (Figures 13 through 15) are based on January 1, 1995 (thus covering model years 1971 through 1995). Figure 16 is based at January 1, 1985 (thus, covering model years 1961 through 1985). Therefore, Figures 15 and 16 differ only by the model years covered.

Since both the horizontal and vertical scales vary among these four graphs, care should be taken in making comparisons between these figures.

Figure 13

**Comparison of Predictions for Mean 24-Hour Diurnal Emissions
60° to 84° F Cycle -- Per In-Use Vehicle
(As of January 1, 1995)**

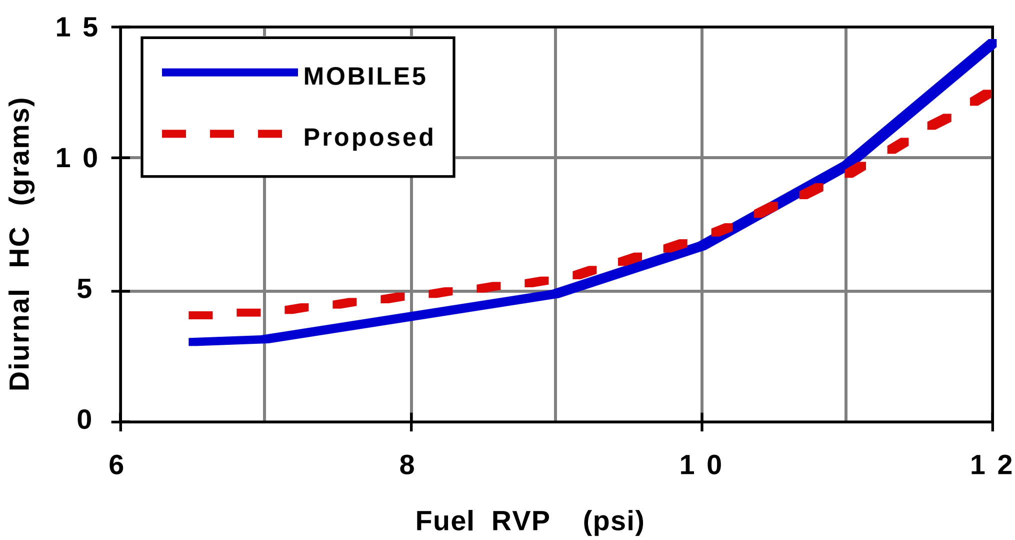


Figure 14

Comparison of Predictions for Mean 24-Hour Diurnal Emissions
72° to 96° F Cycle -- Per In-Use Vehicle
(As of January 1, 1995)

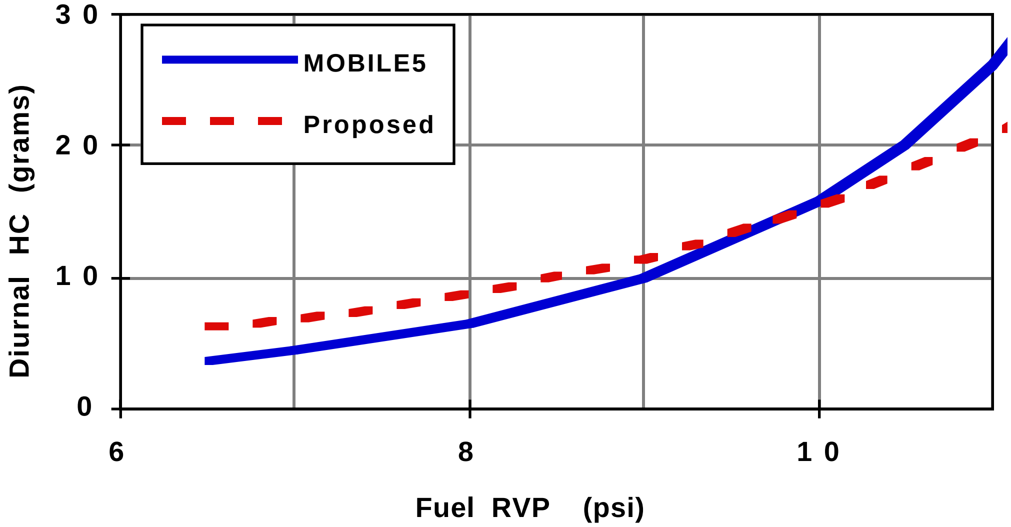


Figure 15

Comparison of Predictions for Mean 24-Hour Diurnal Emissions
82° to 106° F Cycle -- Per In-Use Vehicle
(As of January 1, 1995)

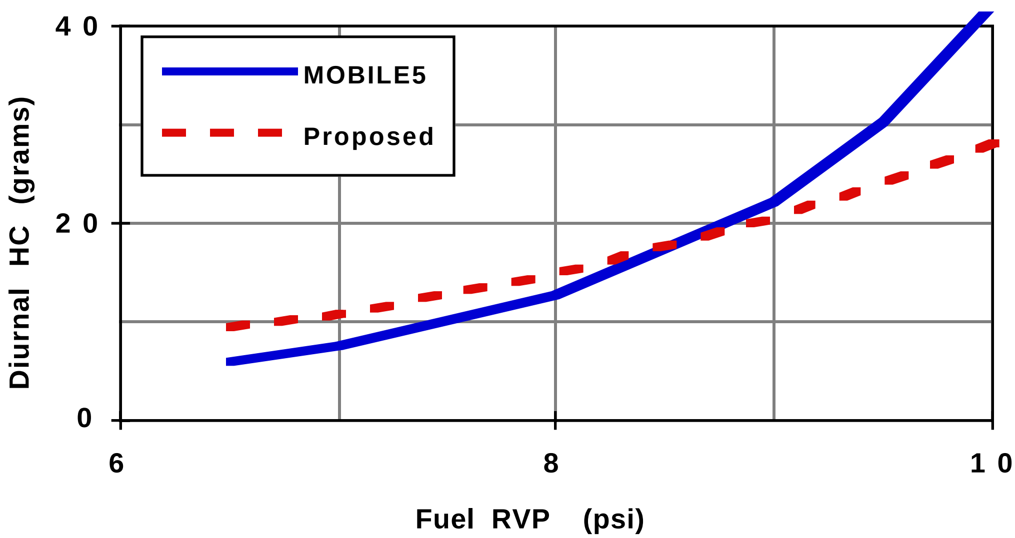
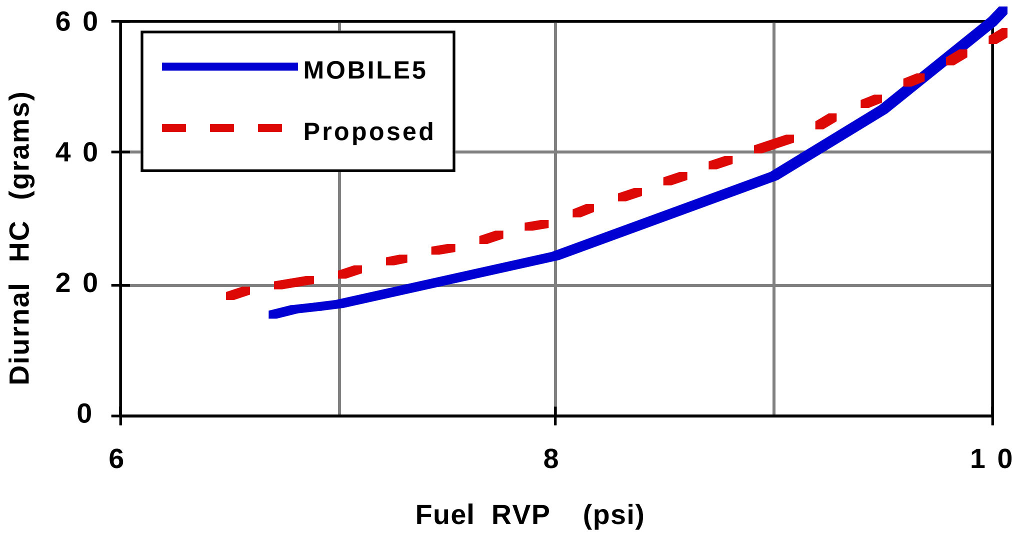


Figure 16

Comparison of Predictions for Mean 24-Hour Diurnal Emissions
82° to 106° F Cycle -- Per In-Use Vehicle
(As of January 1, 1985)



Based on examinations of these four graphs, we made the following observations:

- For the lowest temperature cycle (i.e., daily temperatures cycling between 60° and 84°F), the newly proposed methods of predicting fleet diurnal emissions produce results quite similar to MOBILE5 for the full range of fuel RVPs. (Figure 13.)

- For the two higher temperature cycles, these newly proposed methods of predicting diurnal emissions produce results similar to MOBILE5 for fuel RVPs up to 10 psi, which is a reasonable upper bound for in-use fuel RVP at those temperatures. (Figures 14 through 16.)

- The new approach (compared to MOBILE5) predicts slightly higher diurnal emissions for the lower RVP fuels and the reverse (i.e., lower diurnal emissions) for the higher RVP fuels. The range of RVPs for which the new estimates are higher than the MOBILE5 estimates varies with the temperature cycle:

  - For the low temperature cycle (i.e., 60° to 84°F), the new approach predicts slightly higher diurnal emissions for fuel RVPs up through 11 psi. For fuel RVPs near 7 psi, the new approach predicts less than 0.9 grams of HC (above the MOBILE5 estimates) per day per vehicle undergoing a full (24-hour) diurnal. This difference gradually shrinks to zero as the fuel RVP nears 11 psi. For fuel RVPs above 11 psi, the new estimates are slightly lower than the MOBILE5 estimates.

- For the moderate temperature cycle (i.e., 72° to 96°F), the new approach predicts slightly higher diurnal emissions for fuel RVPs up through 10 psi. For fuel RVPs above 10 psi, the new estimates are lower than the MOBILE5 estimates. For RVPs above 11 psi (an unlikely occurrence with this temperature cycle), the two models move farther apart.

- For the high temperature cycle (i.e., 82° to 106°F), the new approach predicts slightly higher diurnal emissions for fuel RVPs up through 8.5 psi for the in-use fleet as of January 1995 (Figure 15). For fuel RVPs above 8.5 psi, the new estimates are lower than the MOBILE5 estimates. For RVPs above 10 psi (an unlikely occurrence with this temperature cycle), the two models move farther apart. A snapshot of the in-use fleet as of January 1985 (Figure 16) yields similar results.

5.3 Comparisons of Diurnal Emissions from Vehicles Certified to the Enhanced Evaporative Control Standards

In the preceding section, we compared, for 1995 and older model year vehicles, these proposed estimates with those predicted by the MOBILE5 model. In this section, we perform a similar comparison of the two estimates for the vehicles certified to the enhanced evaporative standard (i.e., the 1999 and newer along with some 1996 through 1998 model year vehicles).

Repeating the process used to create Figures 11 and 12 but with January 1, 2020 as the base produced the two following figures (Figures 17 and 18). Visual inspections of Figures 17 and 18 leads to the following conclusions:

- This proposal predicts substantially lower diurnal emissions for these new vehicles than does MOBILE5.

- For vehicles between 10 and 25 years of age, this proposal predicts a substantial rise in the diurnal emissions of the in-use fleet (on a per vehicle basis).

  This increase in emissions is driven primarily by the increasing numbers of gross liquid leakers. With improvements in the durability of evaporative emission control systems, discussed in Section 4.0, the high emissions associated with "gross liquid leakers" eventually drive the overall fleet average diurnal emissions curve. This is despite the fact that their predicted rate of occurrence among vehicles certified to the enhanced evaporative standards is very low (less than two percent at age 25).

Thus, modifying assumptions on the frequency of gross liquid leakers as a function of age among these vehicles would significantly affect the graphs for "Proposal" in Figures 17 and 18, with that curve remaining much flatter throughout. As we have no information of the impact of the new enhanced evaporative control requirements on the rate of occurrence of "gross liquid leakers," we are especially interested in comments in this area.

Figure 17

For Enhanced Evaporative Control Vehicles
Comparison of Predictions for In-Use Diurnal Emissions by Age
60° to 84° F Cycle -- Using 9.0 RVP Fuel
(Non-I/M Area)

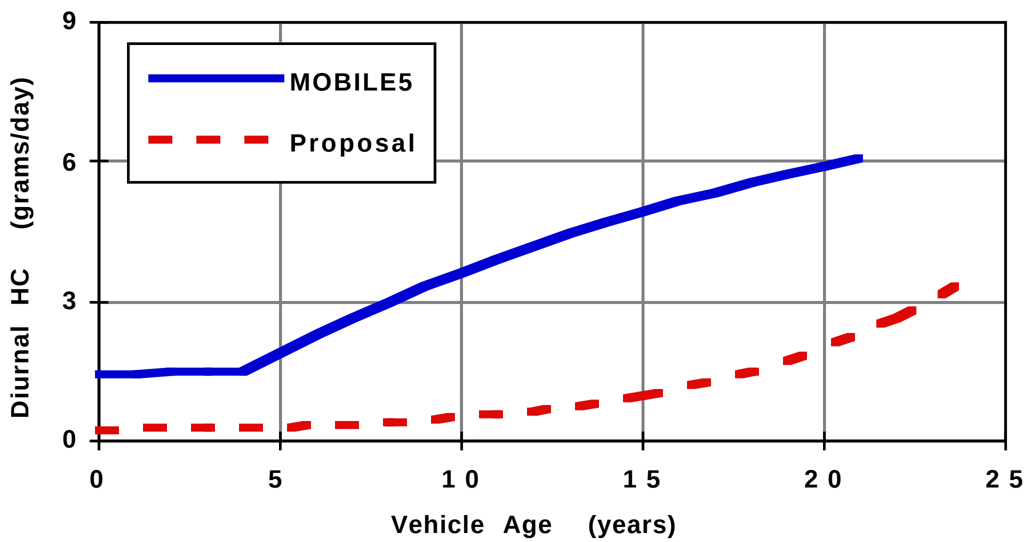
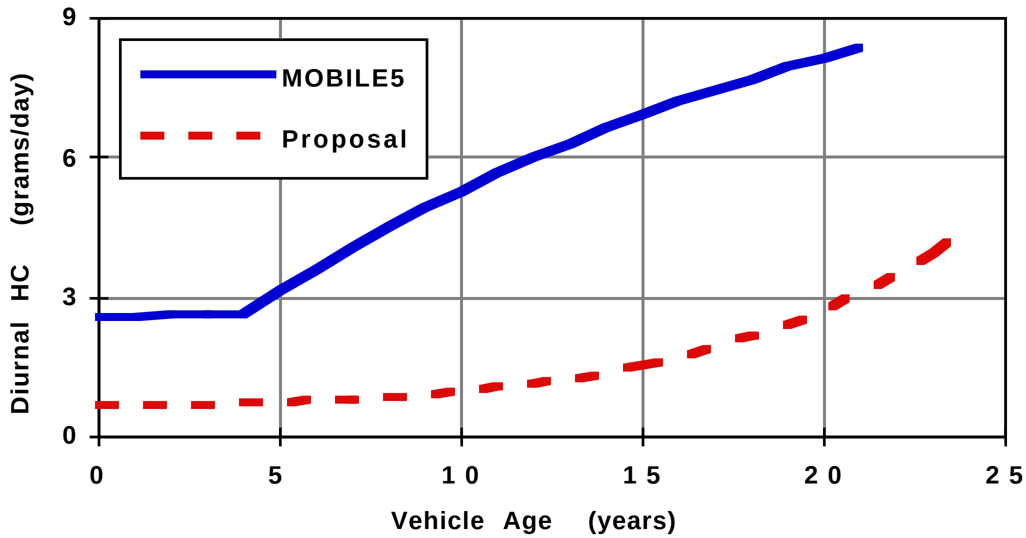


Figure 18

**For Enhanced Evaporative Control Vehicles
Comparison of Predictions for In-Use Diurnal Emissions by Age
82° to 106° F Cycle -- Using 7.0 RVP Fuel
(Non-I/M Area)**



6.0 Summary

Estimates of evaporative emissions in MOBILE6 will be modeled based on their type:

- resting loss emissions,
- running loss emissions,
- hot soak emissions, and
- diurnal emissions.

Each of these types will be calculated based on whether the individual vehicles:

- are gross liquid leakers,
- failed the pressure test,
- failed only the purge test, or
- passed both the purge and pressure tests.

Once the estimated evaporative emissions of each sub-strata is calculated, they will be weighted together using the equations developed in this report.

Very preliminary analyses suggest that for the full-day diurnal (see the footnote on page 27), the proposals for MOBILE6 would:

- predict lower diurnal emissions than does MOBILE5 for the 1999 and newer vehicles,

- predict similar diurnal emissions than does MOBILE5 for the 1986-1995 model year vehicles, and

- predict higher diurnal emissions than does MOBILE5 for the 1985 and older vehicles.

Based on this proposal, we can perform a simplified analysis to estimate the effect (benefit) on diurnal emissions of reducing fuel RVP:

- In each of the four figures (Figure 13 through 16), the MOBILE5 graph is steeper than the graph of the new approach. The lower slopes associated with the MOBILE6 proposal will result in smaller decreases in predicted diurnal emissions associated with a change in fuel RVP than the corresponding changes predicted by MOBILE5.

- Analyses performed to calculate the effect (e.g., either the cost per ton or the benefit) will make RVP control programs slightly less attractive.

- The difference in the predicted effect of lowering fuel RVP is small for lower RVP fuels. Thus, estimating the effects of reducing the fuel RVP from 8 psi (or from a lower value) will be similar under both methods.

7.0 References

1) Larry Landman, "Evaluating Resting Loss and Diurnal Evaporative Emissions Using RTD Tests," Report numbered M6.EVP.001, July 1999.

2) Larry Landman, "Modeling Hourly Diurnal Emissions and Interrupted Diurnal Emissions Based on Real-Time Diurnal Data," Report numbered M6.EVP.002, July 1999.

3) Larry Landman, "Modeling Diurnal and Resting Loss Emission from Vehicles Certified to the Enhanced Evaporative Standards," Report numbered M6.EVP.005, November 1998.

4) Larry Landman, "Evaporative Emissions of Gross Liquid Leakers in MOBILE6," Report numbered M6.EVP.009, June 1999.

5) Louis Browning, "Update of Hot Soak Emissions Analysis" prepared by Louis Browning of ARCADIS Geraghty & Miller, Inc. for EPA, Report numbered M6.EVP.004, September 1998

6) Larry Landman, "Estimating Running Loss Evaporative Emissions in MOBILE6," Report numbered M6.EVP.008, June 1999.

7) D. McClement, "Real World Evaporative Testing of Late Model In-Use Vehicles, CRC Project E-41", Prepared for the Coordinating Research Council, Inc. by Automotive Testing Laboratories, Inc., December 17, 1998.

8) D. McClement, "Raw Fuel Survey in I/M Lanes", Prepared for the American Petroleum Institute and the Coordinating Research Council, Inc. by Automotive Testing Laboratories, Inc., June 10, 1998.

Appendix A

Estimates of Purge/Pressure Strata Size by Vehicle Age For 1995 and Older Model Years Vehicles (For Non-I/M Areas)

Vehicle Age (years)	Failing Pressure Test	Failing Only Purge Test	Passing Both Purge and Pressure Tests
0	3.23%	1.77%	95.00%
1	3.27%	1.80%	94.93%
2	3.40%	1.88%	94.72%
3	3.62%	2.02%	94.36%
4	3.96%	2.23%	93.81%
5	4.44%	2.53%	93.03%
6	5.10%	2.95%	91.96%
7	5.99%	3.51%	90.51%
8	7.18%	4.25%	88.57%
9	8.78%	5.23%	85.99%
10	10.91%	6.47%	82.62%
11	13.70%	8.00%	78.30%
12	17.30%	9.76%	72.94%
13	21.79%	11.61%	66.60%
14	27.12%	13.29%	59.58%
15	33.07%	14.51%	52.42%
16	39.19%	15.06%	45.76%
17	44.90%	14.95%	40.14%
18	49.76%	14.41%	35.84%
19	53.50%	13.70%	32.80%
20	56.16%	13.03%	30.81%
21	57.92%	12.50%	29.58%
22	59.02%	12.13%	28.85%
23	59.66%	11.89%	28.45%
24	60.03%	11.74%	28.23%
25	60.24%	11.65%	28.11%

Appendix B

Predicted Frequency of Occurrence of "Gross Liquid Leakers" by Emission Type and Vehicle Age For 1995 and Older Model Years Vehicles

(Reproduced from Report Number: M6.EVP.009 **[4]**)

Vehicle Age (years)	Resting Loss / Diurnal	Running Loss	Hot Soak
0	0.02%	0.05%	0.07%
1	0.03%	0.07%	0.10%
2	0.04%	0.11%	0.15%
3	0.06%	0.16%	0.23%
4	0.09%	0.24%	0.33%
5	0.13%	0.35%	0.48%
6	0.19%	0.50%	0.70%
7	0.27%	0.72%	1.00%
8	0.39%	1.02%	1.41%
9	0.55%	1.40%	1.95%
10	0.78%	1.88%	2.64%
11	1.08%	2.43%	3.48%
12	1.49%	3.02%	4.46%
13	2.00%	3.61%	5.54%
14	2.63%	4.16%	6.67%
15	3.36%	4.62%	7.83%
16	4.15%	5.00%	8.95%
17	4.97%	5.29%	10.00%
18	5.75%	5.51%	10.94%
19	6.46%	5.66%	11.75%
20	7.05%	5.77%	12.42%
21	7.54%	5.84%	12.94%
22	7.91%	5.89%	13.34%
23	8.19%	5.93%	13.63%
24	8.40%	5.95%	13.85%
25	8.55%	5.97%	14.00%

Appendix C

Estimates of Purge/Pressure Strata Size by Vehicle Age For 1999 and Later Model Years Vehicles (For I/M Areas*)

Vehicle Age (years)	Failing Pressure Test	Failing Only Purge Test	Passing Both Purge and Pressure Tests
0	0.76%	0.42%	98.83%
1	0.76%	0.42%	98.82%
2	0.77%	0.42%	98.81%
3	0.78%	0.43%	98.79%
4	0.80%	0.44%	98.76%
5	0.82%	0.46%	98.72%
6	0.85%	0.47%	98.67%
7	0.89%	0.50%	98.62%
8	0.93%	0.52%	98.54%
9	0.98%	0.56%	98.46%
10	1.04%	0.60%	98.36%
11	1.11%	0.64%	98.25%
12	1.20%	0.69%	98.11%
13	1.29%	0.75%	97.95%
14	1.41%	0.82%	97.77%
15	1.54%	0.91%	97.56%
16	1.69%	1.00%	97.31%
17	1.86%	1.11%	97.03%
18	2.06%	1.23%	96.71%
19	2.30%	1.37%	96.34%
20	2.56%	1.52%	95.92%
21	2.87%	1.69%	95.44%
22	3.22%	1.88%	94.90%
23	3.62%	2.08%	94.30%
24	4.07%	2.29%	93.64%
25	4.57%	2.51%	92.92%

* This assumes that the I/M program requires repairs to vehicles with a MIL that indicates that there is a problem.

Appendix D

Estimates of Strata Size by Vehicle Age For 1999 and Later Model Years Vehicles (For Non-I/M Areas*)

Vehicle Age (years)	Failing Pressure Test	Failing Only Purge Test	Passing Both Purge and Pressure Tests
0	0.76%	0.42%	98.83%
1	0.76%	0.42%	98.82%
2	0.77%	0.42%	98.81%
3	0.78%	0.43%	98.79%
4	0.85%	0.47%	98.68%
5	0.94%	0.53%	98.53%
6	1.06%	0.60%	98.34%
7	1.21%	0.70%	98.09%
8	1.39%	0.81%	97.79%
9	1.61%	0.95%	97.43%
10	1.87%	1.12%	97.01%
11	2.18%	1.31%	96.52%
12	2.53%	1.53%	95.94%
13	2.94%	1.79%	95.27%
14	3.42%	2.09%	94.49%
15	3.97%	2.44%	93.59%
16	4.62%	2.83%	92.55%
17	5.36%	3.29%	91.35%
18	6.21%	3.81%	89.98%
19	7.20%	4.40%	88.40%
20	8.34%	5.05%	86.61%
21	9.64%	5.78%	84.57%
22	11.13%	6.58%	82.29%
23	12.82%	7.44%	79.74%
24	14.73%	8.34%	76.92%
25	16.86%	9.27%	73.86%

Up through the age of three (3) years, the values are identical to those in Appendix C.

* This assumes that either the geographic area has no I/M program or that the existing I/M program does not include a check of the OBD MIL.

Appendix E

Predicted Frequency of Occurrence of "Gross Liquid Leakers" by Emission Type and Vehicle Age For 1999 and Newer Model Years Vehicles

Vehicle Age (years)	Resting Loss / Diurnal	Running Loss	Hot Soak
0	0.02%	0.05%	0.07%
1	0.03%	0.06%	0.09%
2	0.03%	0.07%	0.10%
3	0.04%	0.09%	0.13%
4	0.04%	0.11%	0.15%
5	0.05%	0.13%	0.19%
6	0.06%	0.16%	0.23%
7	0.08%	0.20%	0.27%
8	0.09%	0.24%	0.33%
9	0.11%	0.29%	0.40%
10	0.13%	0.35%	0.48%
11	0.16%	0.42%	0.58%
12	0.19%	0.50%	0.70%
13	0.23%	0.61%	0.83%
14	0.27%	0.72%	1.00%
15	0.33%	0.86%	1.19%
16	0.39%	1.02%	1.41%
17	0.47%	1.20%	1.66%
18	0.55%	1.40%	1.95%
19	0.66%	1.63%	2.28%
20	0.78%	1.88%	2.64%
21	0.92%	2.14%	3.04%
22	1.08%	2.43%	3.48%
23	1.27%	2.72%	3.96%
24	1.49%	3.02%	4.46%
25	1.73%	3.32%	4.99%