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Evaluating Multiple Day Diurnal Evaporative Emissions Using RTD Tests

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Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

ABSTRACT

In parallel reports (M6.EVP.001 and M6.EVP.002), EPA estimated the diurnal emissions produced by vehicles that have been parked for up to one full day (24 hours). This report documents the method used in MOBILE6 for estimating the diurnal emissions from vehicles parked for more than 24 hours (i.e., multiple days).

This report was originally released (as a draft) in January 1999. This current version is the final revision of that draft. This final revision incorporates suggestions and comments received from stakeholders during the 60-day review period and from peer reviewers.

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Evaluating Multiple Day Diurnal Evaporative Emissions Using RTD Tests

Report Number M6.EVP.003

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1.0 INTRODUCTION and BACKGROUND

This report documents an analysis of diurnal evaporative emissions from light-duty vehicles (LDVs) and light-duty trucks (LDTs) occurring over periods of more than one day. Results of this study will be used in MOBILE6 in conjunction with estimates of vehicle and truck activity and estimates of evaporative emissions for shorter periods to obtain total diurnal emission values.

The underlying causes of diurnal evaporative emissions are discussed at length in several reports[1,2,3]. By definition, diurnals are those emissions associated with daily temperature change, its effect on vaporization of a vehicle’s fuel, and the expansion of fuel vapor. The evolution of technology and regulations is assumed to influence diurnal emission rates. These trends also are discussed in the references cited above. In the modeling of multiple day diurnals presented here, several categories of vehicles are considered, based on model year, fuel metering, and the vehicle's performance on the purge and pressure tests[1]. These are chosen to achieve consistency with groupings employed in the MOBILE emissions inventory model.

2.0 DATA SOURCES

In this analysis, EPA considered real-time diurnal (RTD) test data from testing programs (i.e., work assignments)

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[1] Landman, L. "Evaluating Resting Loss and Diurnal Evaporative Emissions Using RTD Tests," Report No. M6.EVP.001.

[2] Heirigs, P.L. and R.G. Dulla, "Analysis of Real-Time Evaporative Emissions Data," Sierra Research, Report No. SR97-12-01, December, 1997.

[3] Haskew, H.H. and T.F. Liberty, "Diurnal Emissions from In-Use Vehicles," Coordinating Research Council, CRC E-9, January, 1998.

performed under contract for EPA. The data consist of hourly values of HC emissions (in grams) measured under varying conditions of fuel Reid vapor pressure (RVP) and ambient temperature. (The actual test results are provided with the report identified in reference 1.) Daily totals are obtained directly from these hourly values.

The RTD testing performed for EPA was done by its testing contractor (Automotive Testing Laboratories) over the course of five (5) work assignments from 1994 through 1996 (performed under three different EPA contracts). A total of 119 light-duty vehicles (LDVs) and light-duty trucks (LDTs) were tested in these programs. (That number was reduced to 118 because the status of one of the test vehicles on the purge and pressure tests could not be determined.) Table 1 (below) displays the distribution of those 118 vehicles and individual tests by several parameters. Of special interest is the length of the tests, ranging from 33 to 72 hours.

Table 1

Distribution of EPA Vehicles and Tests

			------- Test Duration (hours) -------							
			33 Hours		**38 Hours**		**72 Hours**		**Total**	
MODEL YEAR	**FUEL METERING**	**PURGE/ PRESSURE**	**Veh**	**Tests**	**Veh**	**Tests**	**Veh**	**Tests**	**Veh**	**Tests**
Pre-80	CARB	F/P	1	6	--	--	--	--	1	6
		P/F	2	12	1	4	1	4	4	20
		P/P	1	6	--	--	--	--	1	6
80-85	CARB	F/P	5	24	--	--	--	--	5	24
		P/F	5	19	--	--	--	--	5	19
		P/P	--	--	2	8	6	27	8	35
	FI	F/P	4	21	--	--	--	--	4	21
		P/F	2	12	--	--	--	--	2	12
		P/P	3	12	--	--	--	--	3	12
86-95	CARB	F/P	1	4	--	--	--	--	1	4
		P/F	3	12	--	--	--	--	3	12
		P/P	2	6	--	--	1	1	3	7
	FI	F/P	17	96	1	4	1	6	19	106
		P/F	19	96	1	4	1	4	21	104
		P/P	20	88	2	8	16	80	38	176
ALL (Totals)			85	414	7	28	26	122	118	564

More complete descriptions of these data are found in the reports cited earlier.

In addition, the two EPA vehicles identified as "gross liquid leakers" (GLLs) are omitted from these analyses. The emissions of these vehicles are large, tending to skew estimates for non-leakers, while the mechanisms by which emissions are produced are quite different from the two groups. EPA will treat multiple day diurnal emissions from gross liquid leakers as unchanging from day to day.

Other reports on diurnal emissions utilize data from a second set of testing programs performed for the Coordinating Research Council (CRC). (See the report identified in reference 1.) However, because all those additional tests were run for 24 hours only, and thus yield no information on multiple day emissions, they were not used in this current study.

CRC conducted another RTD program (Task VE-4) in which ten 1992-97 model year PFI vehicles (passing both the pressure and purge tests) were tested using the full 72-hour RTD test. These vehicles provide additional results to the stratum that EPA already had the largest amount of test data. Also, the information provided with these results were not in sufficient detail to allow the EPA and CRC data to be merged.

3.0 METHODOLOGY

This work involves estimating the change in diurnal evaporative emissions from the first day to later days. In the MOBILE model, these estimates will be used to determine emissions for full Days 2 and 3 given total emissions based on Day 1. These in turn can be subdivided into hourly values as needed.

Factors influencing the RTD (and diurnal) emissions from individual vehicles include fuel metering technology, model year groupings, and outcome of purge and pressure tests performed on the vehicle. Ambient temperature and fuel volatility also are known to play a central role.

The results of the RTD tests allow us to estimate both the diurnal emissions and the resting loss emissions. (The diurnal emissions being the total RTD results minus the resting loss emissions.) In these analyses, we are actually modeling the changes in the RTD results (for each day). Thus, after predicting the RTD for Days 2 and 3, we must subtract the corresponding estimated resting loss emissions to obtain the diurnal emissions.

3.1 Model Form

In the previous draft of this report (dated January 1999), EPA modeled the natural logarithm of emissions as a linear function of the factors influencing the RTD emissions (described in Section 3.0). Although this approach has a number of advantages, it also has some significant weaknesses (as identified by two of the reviewers).

Therefore, in response to comments from two of the reviewers, EPA altered the form of the model. In MOBILE6, the diurnal emissions for a successive day are modeled as a linear combination of:

1. the midpoint temperature (in degrees Fahrenheit) of the day (i.e., the mean of the maximum and minimum daily temperatures),
2. the Reid vapor pressure (RVP) of the tank fuel in pounds per square inch (psi),
3. the product of the midpoint temperature and the RVP (i.e., an interaction term), and
4. the full-day (predicted) diurnal emissions of the previous day.

Several dummy variables were used to produce different sets of vehicle parameters, thus, creating the categories (strata) that are used in MOBILE6. These (categorical) variables (used to switch on or off the factors of fuel delivery, purge/pressure test status, and model year range) are:

- the status ("Pass" or "Fail") of the evaporative control system of the vehicle, based on the performance of two functional tests (pressure test and purge test),
- the fuel delivery system of the vehicle (i.e., fuel injected versus carbureted), and
- two variables to distinguish among the three model year ranges (i.e., pre-1980, 1981-85, and 1986-95).

Thus, the form used to model the full-day diurnal emissions (in grams) of the second day ("**D2**") is given below as equation **[1]**:

$$D2 = A + (B * T) + (C * R) + (D * T * R) + (E * D1) \qquad [1]$$

Where:

T = Midpoint Temperature (i.e., [Min_Temp + Max_Temp] / 2) (in degrees Fahrenheit)

R = Fuel RVP (in psi)

D1 = RTD test result (grams) for the first day.

Dividing equation **[1]** by the diurnal emissions of the first day ("**D1**") yields an estimate of the ratio of the diurnal emissions of the second day to the first day. MOBILE6 actually uses these ratios to estimate the diurnal emissions of the second day.

Similarly, the form used to model the full-day diurnal emissions (in grams) of the third day ("**D3**") is given below as equation **[2]**:

$$D3 = A + (B * T) + (C * R) + (D * T * R) + (E * D2) \qquad [2]$$

Similarly, dividing the preceding equation **[2]** by the diurnal emissions of the second day ("**D2**") yields an estimate of the ratio of the diurnal emissions of the third day to the second day. MOBILE6 actually uses these ratios to estimate the diurnal emissions of the third (and later) days.

3.2 Model Estimation

The above models were fitted using an ordinary least squares regression. The diurnal emissions of the previous day (which account for additional variation) effectively fits a different intercept term to each vehicle and helps produce sharper estimates of the coefficients shown above. The goal of the analysis was to obtain point estimates of the linear combinations of the type shown in equations **[1]** and **[2]** (in Section 3.1). That approach is adopted in the analysis reported below.

Because the available data include tests of varying length, it is difficult to compare emission values from all tests for the purpose of estimating full day changes. In particular, complete 72-hour tests are available in only six of the model year, technology, and pressure purge test status categories. However, as seen in Table 1, there are a large number of 33-hour and 38-hour tests, and these provide more complete coverage of the categories. These tests give some indication of change in evaporative emissions from the first day to the second. One way to use these data is to consider only the first nine hours of each day, since the 33-hour tests give only that number of hours in Day 2. If it is assumed that the total emissions in the first nine hours are comparable across days then the effective data set numbers 564 tests (almost a five-fold increase).

4.0 INITIAL RESULTS

The two models (i.e., equations **[1]** and **[2]**) were fitted to the 9-hour data described above, one for Days 1 and 2, and the other for Days 2 and 3. Also, these two models were fitted to the (smaller) 72-hour data set. Regression coefficient estimates were computed using the SAS GLM procedure.

4.1 Effect of Fuel Metering, Pressure/Purge Status, and Model Year

In modeling the Day_2 or Day_3 diurnal emissions (i.e., equations **[1]** and **[2]**), neither of the model year (categorical) terms is statistically significant. Therefore, as a first step toward simplification, the model year factor was removed from the analysis of both models.

In the regression analysis of Day-2 versus Day-1 RTD emissions, after removing the two categorical model year terms and refitting the first model (equation **[1]**), all of the resulting (analytical) terms are statistically significant. Also, the categorical variable for fuel metering (FM) is significant at the five percent level.

However, two of the three purge/pressure groupings ("Fail Pressure" and "Fail Only Purge") do not differ significantly (when the test result are compared on a pairwise basis). As a result, they were combined into a single group "FAIL" (fail one or both tests). This combined group ("FAIL") does differ significantly from the remaining group "PASS" (pass both tests). Therefore, a further simplification is used in which a vehicle is classified as "PASS" (pass both tests) or "FAIL" (fail one or both tests). The output of this regression analysis is given in Appendix A. The coefficients produced by this regression are shown below in Table 2.

Table 2

Coefficients to Estimate Second Day Diurnal By Strata

	Passing Both Purge and Pressure		Failing Either Purge or Pressure	
Coeff	**FI**	**Carb**	**FI**	**Carb**
A	47.48	49.06	48.61	50.19
B	-0.70	-0.70	-0.70	-0.70
C	-8.11	-8.11	-8.11	-8.11
D	0.12	0.12	0.12	0.12
E	0.74	0.74	0.64	0.64

NOTE: The values for the coefficients "**B**," "**C**," and "**D**" in the preceding table do not change by stratum. However, we may want the flexibility of allowing them to vary as more data become available.

However, following this same approach (i.e., removing the two categorical model year terms and then refitting the second model), yields terms that are **NOT** statistically significant. For this "Day 2 to Day 3" analysis, the purge/pressure test terms are not statistically significant, possibly because most (23 of the 26) of the vehicles tested for the full three days were from the single pass/pass purge/pressure group. The categorical variable distinguishing between the fuel-injected vehicles and the carbureted vehicles was also **NOT** statistically significant, possibly because most (18 of the 26) of the vehicles tested for all three days were from the fuel-injected group.

After removing the (categorical) variables for fuel delivery system and for the results on the Purge/Pressure tests, the regression was run once again. For this Day-3 versus Day-2 analysis, all of the terms are statistically significant. The output of this analysis is given in Appendix A. The results of this regression analysis are shown (below) in Table 3.

Table 3

Coefficients to Estimate Third Day Diurnal
For ALL Strata

Coefficients	**Values**
A	12.25
B	-0.21
C	-2.61
D	0.04
E	0.81

4.2 Special Cases

Several situations are not covered by actual test data. In these cases, EPA made assumptions on how to handle them in the MOBILE6 model.

4.2.1 Diurnal Emissions for Periods Longer than Three Days

For MOBILE6, EPA assumes that the diurnal emissions stabilize following Day 3. That is, for the relatively small number of vehicles parked for more than three days, the diurnal emissions for the fourth and later days will be identical to the diurnal emissions of the third day.

This appears reasonable since the equations (models) described by Tables 2 and 3 do not predict large changes among the first three days of diurnal emissions. For the case represented by the largest number of tests (i.e., fuel injected vehicles that pass both pressure and purge tests), an argument could be made for modeling continued positive but decreasing changes in diurnal evaporative emissions for succeeding days. That is not proposed here since we lack data with which to form estimates.

4.2.2 Diurnal Emissions of "Gross Liquid Leakers" (GLLs)

In a series of parallel reports (see the report identified in reference 1), we noted that for a small number of vehicles, the primary mechanism of evaporative emissions was the substantial leakage of liquid gasoline (as opposed to simply vapor leaks). In each of those reports, such vehicles were referred to as "Gross Liquid Leakers" (GLLs).

For MOBILE6, EPA assumes that the quantity of leaking gasoline will remain unchanged for each day that the vehicle is parked. Thus, the diurnal emissions for GLLs for each day will be identical to the diurnal emissions of the first day.

4.2.3 Diurnal Emissions of Vehicles Certified Using the Enhanced Evaporative Test Procedure ("ETPs")

Beginning with the 1996 model year, manufacturers began phasing in vehicles certified to the new enhanced evaporative test procedure (ETPs). Since these ETPs were designed to meet a more stringent set of evaporative standards, the assumptions (used in MOBILE6) predict very low diurnal emissions for the first day (assuming that the evaporative control system is functioning properly). These first day diurnal emission values are lower than the averages used to generate the model (i.e., equation **[1]**). Thus, these vehicles are outside the range of the sample data.

MOBILE6 would normally model second day diurnal emissions from ETP vehicles with properly functioning evaporative control systems using the first column in Table 2 (fuel-injected vehicles that pass both the purge and pressure tests). However, applying this equation results in predicting the diurnal emissions from the second day to be substantially higher than actually measured (in other programs). The limited amount of actual data on these vehicles suggest that there is little if any difference among the emissions for the three days of the RTD test.

Therefore, in MOBILE6, the diurnal emissions for ETPs with properly functioning evaporative control systems for all days will be identical to the diurnal emissions of the first day.

4.2.4 Avoid Having "FAILING" Vehicles With Lower Emissions Than "PASSING" Vehicles

For the scenarios actually tested, equations **[1]** and **[2]** predict that the diurnal emissions of vehicles failing either the purge or pressure tests will be higher than those of vehicles passing both tests (all other parameters being equal). However, it is mathematically possible for those equations to predict higher diurnal emissions for "passing" vehicles than for "failing" vehicles. Since this situation is not reasonable, we will limit ("cap") the diurnal emissions such that:

- The diurnal emissions of the vehicles that fail only the purge test will not exceed the diurnal emissions of the vehicles that fail the pressure test.
- The diurnal emissions of the vehicles that pass both the purge and pressure tests will not exceed the diurnal emissions of the vehicles that fail only the purge test.

4.2.5 Setting a Lower Bound for the Ratios of Consecutive Days

For the scenarios actually tested, the ratios of consecutive day diurnal emissions predicted by equations **[1]** and **[2]** closely approximates the ratios of the actual test vehicles. However, it is mathematically possible for those ratios to be much too small for some untested combination of factors. Hence, we will limit ("cap") the ratios such that:

- The ratio of Day_2 to Day_1 will not be smaller than the " **E** " coefficient of equation **[1]**.
- The ratio of Day_3 to Day_2 will not be smaller than the " **E** " coefficient of equation **[2]**.

4.2.6 Comparison to MOBILE5

Equations **[1]** and **[2]** predict smaller changes in day-to-day diurnal emissions in MOBILE6 than were predicted in MOBILE5. However, the predictions in MOBILE5 were based on theoretic models rather than on actual multi-day testing. EPA believes that these new predictions, that are based on actual multi-day diurnal (i.e., 72-hour RTD) tests, are more realistic. Thus, EPA will use in MOBILE6 the factors described in this report.

5.0 CONCLUSION

Day-to-day diurnal evaporative emissions are found to change over the first three days for several combinations of a vehicle’s fuel delivery system and pressure/purge test status. Temperature and fuel vapor pressure effects also are evident. Estimates of these changes based on equations **[1]** and **[2]** (and Tables 2 and 3), as modified by the special cases in Section 4.2, are used in MOBILE6.

The MOBILE model distinguishes between resting loss and diurnal evaporative emissions. The analysis presented here takes a simplified approach, treating resting losses as constant so that any change from one day to the next is entirely due to the diurnal.

In the parallel report entitled "Modeling Hourly Diurnal Emissions and Interrupted Diurnal Emissions Based on Real-Time Diurnal Data" (M6.EVP.002), EPA states that a vehicle would be undergoing the second day of a multi-day diurnal if the diurnal began no later than 8 AM of the previous day which is equivalent to the engine being shut off by 6 AM of the previous day.

For MOBILE6 to actually use estimates of multi-day diurnal emissions, it is obvious that for each hour of the day (or for at least the 18 hours between 6 AM and midnight), we must know the percent of the fleet that has been soaking for "n" hours (n = 1, 2, 3, . . . , 72). The analysis that yields this distribution of fleet activity can be found in report number M6.FLT.006 (entitled "Soak Length Activity Factors for Diurnal Emissions").

Appendix A

Statistical Output Supporting Table 2

```
                     General Linear Models Procedure

Dependent Variable: HC2
                                     Sum of          Mean
Source                  DF          Squares        Square   F Value       Pr > F

Model                    7      55268.47026    7895.49575    557.04       0.0001

Error                  530       7512.27975      14.17411

Corrected Total        537      62780.75001

                  R-Square             C.V.      Root MSE               HC2 Mean

                  0.880341         39.77774      3.764852               9.464721

Source                  DF      Type III SS   Mean Square   F Value       Pr > F

TMP                      1        368.73554     368.73554     26.01       0.0001
RVP                      1        439.01450     439.01450     30.97       0.0001
TMP*RVP                  1        647.61647     647.61647     45.69       0.0001
HC1                      1      11882.95930   11882.95930    838.36       0.0001
PS                       1        105.43909     105.43909      7.44       0.0066
HC1*PS                   1        170.37081     170.37081     12.02       0.0006
FM                       1        209.38302     209.38302     14.77       0.0001


                                       T for H0:    Pr > |T|   Std Error of
Parameter                Estimate     Parameter=0                Estimate

INTERCEPT             47.48019419            4.09     0.0001    11.61899741
TMP                   -0.70187039           -5.10     0.0001     0.13760917
RVP                   -8.10865443           -5.57     0.0001     1.45699245
TMP*RVP                0.11755584            6.76     0.0001     0.01739135
HC1                    0.74038591           28.95     0.0001     0.02557077
PS                     1.12814549            2.73     0.0066     0.41363019
HC1*PS                -0.10093455           -3.47     0.0006     0.02911322
FM                     1.58318070            3.84     0.0001     0.41191509
```

Appendix A (Continued)

Statistical Output Supporting Table 3

```
                           General Linear Models Procedure

Dependent Variable: HC3
                                         Sum of            Mean
Source                    DF            Squares          Square    F Value      Pr > F

Model                      4        6375.824176     1593.956044     562.77      0.0001

Error                    113         320.053957        2.832336

Corrected Total          117        6695.878132

                    R-Square               C.V.        Root MSE               HC3 Mean

                    0.952201           24.79568        1.682955               6.787288


Source                    DF        Type III SS     Mean Square    F Value      Pr > F

TMP                        1           6.987337        6.987337       2.47      0.1191
RVP                        1           9.853014        9.853014       3.48      0.0648
TMP*RVP                    1          17.397714       17.397714       6.14      0.0147
HC2                        1        2692.480471     2692.480471     950.62      0.0001

Dependent Variable: HC3

                                          T for H0:    Pr > |T|   Std Error of
Parameter                    Estimate    Parameter=0                 Estimate

INTERCEPT                 12.24739357           1.12     0.2659    10.95272601
TMP                       -0.20580431          -1.57     0.1191     0.13103008
RVP                       -2.61263214          -1.87     0.0648     1.40076763
TMP*RVP                    0.04206389           2.48     0.0147     0.01697211
HC2                        0.80699924          30.83     0.0001     0.02617395
```

Appendix B

Response to Peer Review Comments from H. T. McAdams

This report was formally peer reviewed by one peer reviewer (H. T. McAdams). In this appendix, comments from H. T. McAdams are reproduced in plain text, and EPA's responses to those comments are interspersed in indented italics.

> *In order to respond to (and incorporate) comments from the peer reviewer (as well as from stakeholders), this final version of the report has changed substantially from the earlier draft version that was reviewed. Some of those changes have resulted in many of the comments no longer being applicable.*

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Evaluating Multiple Day Diurnal Evaporative Emissions
Using RTD Tests

By

Phil Enns

Report Number M6.EVP.003

Review and Comments
By
H. T. McAdams

1. INTRODUCTION AND SUMMARY

Report Number M6.EVP.003 is herein reviewed in accordance with a letter postmarked February 17, 1999 from Mr. Philip A. Lorang, Environmental Protection Agency (EPA) to Mr. H. T. McAdams, AccaMath Services. The reviewer is tasked to address report clarity, overall methodology, appropriateness of the data sets used, statistical and analytical methodology and the appropriateness of conclusions, with specific attention to data stratification and predictive equations.

These topics are summarized briefly here, and are discussed in more detail, as is deemed necessary, in the body of the report.

- The report is well written, concise and readable. Notation is simple and easy to identify and follow.

- The overall methodology is consistent with that employed in other, similar EPA reports, specifically M6.EVP.001 and M6.EVP.005. The review offers some modifications for possible improvement.

- The datasets used, as in M6.EVP.001 and M6.EVP.005, are far from ideal, but considerable ingenuity is displayed in adapting the available data to the questions at hand. In the review, suggestions are made for possibly extracting even more information from the data.

- Statistical approaches other than regression analysis should be considered, inasmuch as the "variables" of interest are discrete rather than continuous. If regression <u>is</u> used, logarithmic transformation of the response variable may not be necessary and could even have a biasing effect on emission estimates. Alternative approaches are outlined.

- The general thrust of the conclusions is that evaporative emissions vary from day to day. However, the quantitative <u>extent</u> of that variation and how long it takes to decay is subject to question.

It is to be understood that many of the criticisms of M6.EVP.001 and M6.EVP.005 apply to the report being reviewed. For example, in the reports previously reviewed, it was indicated that error bounds are essential to a complete statistical analysis and that care should be taken in stating levels of significance. The report now being reviewed, however, clearly states that the objective of the statistical analysis is to provide <u>point estimates</u> of the various quantities of interest. That being the case, this review eschews the consideration of confidence bounds. Nevertheless, it is recommended that such concerns be considered in subsequent modifications of the MOBILE model.

2. ANALYSIS AND DISCUSSION

The report is subject to several methodological difficulties. Whether regression analysis should be the procedure of choice is a legitimate question, particularly in view of the discrete nature of most of the "variables." And, if a linear model <u>is</u> to be used, is logarithmic transformation appropriate under the present circumstances? A least-squares fit in log space does not guarantee a least-squares fit in the original space, nor does it ensure unbiased or minimum variance estimates. Much depends on the nature of the error distribution and the nature of the response to incremental changes in the predictor variables.

Just how serious these concerns are can not be ascertained without further computations considered to be beyond the scope of this review. It is recommended, however, that other approaches be tried, specifically regression without log transformation, and possibly straightforward Analysis of Variance (ANOVA). It is also suggested that residuals and R-Square be computed both in log space and in the inverse space and that these be compared with results of a non-linear methodology for fitting the data to an equation. Finally, an example is given to show how sampling experiments can be helpful in selecting the most appropriate model.

We agree. We have replaced the logarithmic approach with a simple linear approach.

2.1 Stratification

In view of the fact that most of the variables are dichotomous, estimating day-to-day changes in evaporative emissions comes down to a matter of vehicle classification. Observable classification features, such as fuel-metering systems, model year and pass/fail status re purge and pressure tests provide natural groupings. So far as evaporative emission characteristics are concerned, however, some of these groups may be indistinguishable from others. A primary objective of statistical analysis, therefore, is to determine the minimum number of vehicle classes or strata to span the evaporative emission characteristics of the fleet.

Viewed in this light, the problem would seem to be a candidate for straightforward Analysis of Variance (ANOVA). In such instances, the relative magnitude of <u>within</u> and <u>between</u> groups is the major discriminant, and there exists a variety of procedures and associated software for dealing with such problems.

We have followed this suggestion, reduction of the number of strata in the analysis of "Day_3 to Day_2" data (see the current version of Table 3).

2.2 Model Estimation

The methodology employed in the report is the usual General Linear Model (GLM). The response variable, however, is <u>not</u> diurnal emissions but log(emissions). [Note: here the notation convention is that log (not ln) refers to natural logarithms]. Logarithms of the emission observations were regressed on the variables listed at the top of page 2 in the report. According to the report, an advantage of this representation is that when the equation is differentiated, the derived equation, after being multiplied by 100, yields the percent change in emissions for a unit change in predictor variables.

Justification for this interpretation is given in the Appendix of the report. The derivation given there is mathematically correct, but is usually applied to continuous variables like RVP or temperature. In the present instance, only two of the variables are continuous, and even <u>those</u> two are irrelevant, because they are not entered as interacting with the DAY variable. Strictly speaking, then, the variables that are "differentiated" with respect to DAY do not have a derivative in the usual sense of the word. Rather, the appropriate mathematical discipline is the calculus of finite differences.

The <u>difference</u> in the value of the emission function when a predictor variable is set at its extremes (0 and 1) is what plays the role of "derivative." If there were <u>three</u> points in the function's domain, as there is for the DAY variable, differences can be computed for the second two points just as well as for the first two points. Also, it would be possible to compute a <u>second</u> order difference as the difference between those differences, and that quantity would be analogous to a second derivative in the case of a continuous variable.

We agree. We have dropped the differential approach.

These fine distinctions are not of any particular consequence except to point out that in the discrete realm, we are dealing with simple differences between quantities, and that ratios can be formed without having to resort to logarithmic transformations, which brings its own nuances (and nuisances) to the scene.

An indication of the difficulties that might be encountered is found in the following quotation from the report, page 6.

> The apparent decrease in the failing fuel-injected mean from Day 1 to Day 2 appears inconsistent with the finding of a 13.3% rate of increase. This is explained by the fact that the percent change is derived from the logarithms of the individual emission levels, which has a disproportionate effect [on] larger emission values. For these two subsamples, the means of the logarithms increase (from 1.59 to 1.76) as expected.

This discrepancy is a wake-up call for the possibility of other difficulties associated with a logarithmic transformation. If logarithms can cause "disproportionate effects" here, then perhaps they may be causing difficulties elsewhere, in a way that is not apparent. Indeed, a closer look at the nature of the transformation and how it affects the analysis of the present data is in order.

2.2.1 How Log Transformation Affects Sample Means and Variances

As has been noted, the list of predictor variables reveals the fact that all but <u>two</u> of the predictor variables are discrete and dichotomous. For discrete variables, regression is little more than just a way of classifying data into sets of observations and finding the means for those sets.

It is for this reason that it is appropriate to examine how a logarithmic transformation affects the mean and variance of a simple column of data. The mean is the least-squares estimate of a measure of central tendency, and, if the data are samples from a normal distribution, then the least squares estimate is also the maximum likelihood estimate as well. Let us not forget, however, what sample space we are working in. The sample mean is the most likely estimate of the population of the logarithms of the emissions, but the sample mean, when exponentiated, does not provide the most likely mean of the population of emissions expressed in appropriate units such as gm/mi.

Under certain circumstances, logarithmic transformation has definite advantages in the analysis of emission data and has been extensively used for that purpose. The Complex Model for Reformulated Gasoline (RFG) is a good example. Like any good medicine though, it can have some nasty side effects. Mostly, these effects arise from the fact that what is a summation in emission space becomes an iterated multiplication in log space. That being the case, computing the mean in log space is equivalent to computing the geometric mean in the real world - that is, the N^{th} root of the product of N numbers, N being the sample size.

Consider a normally distributed population of logarithms with mean 0 and variance 1. It can be shown that, if m and s denote respectively the mean and standard deviation of the logarithms, then the mean M and variance V of the antilogs are:

$$M = \exp(m + 1/2\ s^2) \qquad (1)$$

$$V = \exp(2m + 2s^2) - \exp(2m + s^2) \qquad (2)$$

Note that both the mean M and the variance V of the antilogs are functions of both the mean "m" and the variance "v" of the logarithms. Of particular note is the fact that if we just exponentiate the mean logarithmn "m," we will underestimate the mean in emission space. There is an added s^2 in the argument of the exponential that leads to the curious property that the greater the variance of the logarithms, the more the mean of the antilogs is inflated.

From (1), therefore, it is clear that if one computes the mean m for a sample of N normally distributed logarithms, there is only one circumstance under which it is legitimate to take the exponential of m as the mean M of the antilogarithms. That circumstance is when the variance of the sample of logarithms is zero (0). In other words, the transformation is legitimate only if all items in the sample are identical. Otherwise, the transformed logarithm yields the geometric mean, and, of course, if all the observations are identical, then the arithmetic and geometric means are the same.

The impact of these equations can be better appreciated by conducting a simple sampling simulation. A sample of 10,000 random numbers was drawn from a normal distribution with mean 0 and variance 1. Then the 10,000 random numbers were treated as logarithms and their mean and standard deviation were computed. Next, the exponentials of the 10,000 random logarithms were computed and were treated as if they were emissions expressed in appropriate physical units, such as gm/mi. In the table below, sample and population statistics for logs and antilogs are compared.

COMPARISON OF SAMPLE MEAN AND VARIANCE OF 10,000 RANDOM SAMPLES

	Mean	Variance
Sample data for 10,000 random logarithms N(0,1)	-0.0095	1.0049
Exponential transforms of the above statistics	0.9985	2.7316
Statistics for exponentials of 10,000 logs	1.6482	4.9785
Population parameters for N(0,1) logarithms	0	1
Transforms (exponentials) of above parameters	1	2.7883

It is clear that if we transform the mean logarithm just by taking its antilogarithm, then the resulting number, if reported as the mean, is biased downward (from 1.6482 to 0.9985). From Equation (1), it is clear that if the variance of the logarithms has <u>any</u> finite value, then the antilog transform of the mean logarithm is smaller than the mean computed directly from the data. Similarly, if we take the antilogarithm of the variance and report it as the variance of the antilogarithms, it too is biased.

How much these flaws affect the computation of the day to day changes in evaporative emissions is not known, because the required computation is beyond the scope of this assignment. Inasmuch as our interest is in the <u>ratio</u> of one day's emissions to another day's emissions, there may be a compensating effect that tends to alleviate <u>part</u> (but not all) of the error. Nevertheless, it is suggested that the data be reconsidered with the above considerations in mind.

> *We agree. We have replaced the logarithmic approach with a simple linear approach.*

2.2.2 How Logarithmic Transformation Affects Regression

It is correctly remarked in the report that regression provides a least-squares fit to the data. However, the parameters estimated by least squares apply to log space, not to the real world of emissions. Perhaps the most disturbing aspect of the log transformation is that the errors are multiplicative rather than additive.

For example, consider the linear form of the model, as shown on page two (2) of M6.EVP.003:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \ldots b_k x_k \qquad (3)$$

where

$$y = \log(\text{emissions})$$

As written in equation (3), log(emissions) are expressed *deterministically* as a function of x_1, x_2, . . . x_k. Actually, as is well known, the equation has an error term:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \ldots b_k x_2 + \text{err} \qquad (4)$$

where err denotes a random error assumed to be normally distributed. Then, transforming (4) back into emissions space, we have:

$$\text{Emissions} = \exp(b_0 + b_1 x_1 + b_2 x_2 + \ldots b_k x_k) *\exp(\text{err}) \qquad (5)$$

Equation (5) makes it clear that the greater the emissions, the greater the error.

This behavior is not necessarily disadvantageous, however. If a random variable really *is* such that its variance increases with its mean value, then a logarithmic transformation tends to stabilize the variance. This behavior is a legitimate basis for performing a log transformation of the dependent variable when that variable is regressed on one or more predictor variables.

However, if variance *is* independent of the population mean, then the log transformation is disadvantageous, because it is equivalent to giving the larger values in a sample greater weight in determining the regression coefficients. Consequently, the regression coefficients are biased in favor of minimizing the larger residuals at the expense of the smaller residuals. It is as if we are performing a *weighted* least squares estimation in which the weights are proportional to the numbers being fitted.

Performing least squares regression of logarithms is also appropriate in another circumstance. In simple regression, it is assumed that for a given incremental change in a predictor variable, the response increment will be the same regardless of how large the response is. In some instances, however, the response is *proportional* to the value of the response variable. This phenomenon, of course, is the basis for interpreting the regression coefficients as the fractional or percentage change in the dependent variable for a *unit* change in the predictor variable. The Appendix in M6.EVP.003 contains a proof of this interpretation.

The best of both worlds is realized when both of the above circumstances are realized simultaneously. It is conjectured that that circumstance rarely occurs.

It is probably fair to say that logarithmic transformation is most frequently selected not for either of these reason, but because it simplifies the analysis. The General Linear Model can be applied, and we are spared the difficulties of performing a nonlinear minimization of errors.

In the case under consideration, in which most of the variables are dichotomous, it is hard to see why log transformation is preferred to emission space. A hypothetical problem was set up to demonstrate what might happen if only dummy variables are present. The dataset for this demonstration is in Appendix I *[renamed Appendix B-1 in this report]*.

The problem data set contains twenty observations in which the response variable is dependent on three dummy variables that assume the values of either 0 or 1. A simple model is one in which the response variable y is regressed on the dichotomous variables x_1, x_2, and x_3:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 \tag{6}$$

As an alternative, the response variable was logarithmically transformed:

$$yy = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 \tag{7}$$

where yy = log(y).

The regression coefficients under the two models are as follows:

	y-space	yy-space
Intercept	17.6572	2.7624
x_1	12.7385	0.7430
x_2	3.6462	0.1803
x_3	-9.3615	-0.5391

Residuals were computed for both regressions (See Appendix)and are plotted in Figure 1. R-square in y-space is 0.8203 and 0.7981 in yy-space (log space).

	y-space	yy-space*
Sum of residuals	0.0000	3.5901
Residual Std.	3.5202	4.9356

* Computed as the difference between observed responses and exponentiated responses as calculated from the log model.

As predicted, when the responses computed from the log model are transformed to their equivalents in y-space, the residuals are biased and have a larger variance than when computed directly from the simple model in y-space.

The intent of these demonstrations is to emphasize the desirability of doing some "experimental statistics" before deciding on whether the analysis is best served in log space or antilog space. In the case of M6.EVP.003, it is suggested that a simple linear model be considered as an alternative to the log-based model. The effort required is small enough to be executed now, and its implications should be kept in mind in any future modifications of the MOBILE model.

2.2.3 How About Vehicle Effects?

According to the wording of the report, "a vehicle factor was included" in the model. The report goes on to say, "This effectively fits a different intercept term to each vehicle and helps produce sharper [sic] estimates of the [regression] coefficients." No interpretation or measure is given to clarify what the term "sharper" implies.

Removing vehicle effects is essential in a case like this. In the development of the Complex Model for Reformulated Gasoline (RFG), vehicle-to-vehicle differences accounted for some 95% of the variance of the response variable. What is lacking in the present instance is a similar comparison of vehicle effects and effects induced by other sources. Beyond the above quotation regarding "a vehicle factor" and an allusion to intercepts, no further explanation of dealing with that factor is given. And, there is no mention of vehicle effects in the computer print-outs of Tables 2 and 3.

> *The "vehicle factor" that was used in the analysis was the prior day's actual RTD emissions (identified in Appendix A as "HC1" and "HC2"). These "vehicle factors" were used in both the previous draft as well as in this final version.*

The conventional way of dealing with extraneous variables like vehicles is to enter each as a "dummy variable" having two states, 0 and 1, representing respectively absence or presence of that vehicle. There is a loss of one degree of freedom for each vehicle. Vehicle degrees of freedom are not accounted for in the printouts, nor is there any data showing the magnitude of the effects of either individual or aggregated vehicles. The report needs to be more explicit on this point, not only for the purpose of quantifying what is meant by "sharper" estimates, but also to see how vehicle effects compare with DAY effects and other sources of variance.

Finally, no value is given for the intercept in the computer printouts. Presumably that is because the matrix of the normal equations is less than full rank, because the sum of the vehicle vectors is equal to the intercept vector. In that case, either the intercept or some other effect must be taken as inestimable. For present purposes, lack of an intercept is of no concern, because interest is concentrated on the ratio of emissions from one day to another. To scale model estimates up to real-world values, however, an estimate of baseline emissions would be required.

3. APPROPRIATENESS OF CONCLUSIONS

A conclusion of the report is that day-to-day evaporative emissions are found to change over the first three days for several classes of vehicles. The data, though not ideal, supports this conclusion, but AccaMath believes that estimates of the extent of these changes could be improved, even with the present data. Least satisfactory of the conclusions, perhaps, is the implication that after three days the change over time abruptly ends. It would seem natural to expect that after the changes have peaked they might decay exponentially and gradually approach an asymptote. There is no support for the sudden ending. Perhaps there should be one or more really long-term tests to indicate the actual growth and decay curve. Admittedly, this is not a job for day after tomorrow, but might be put on the agenda for later consideration.

> *Running RTD tests for periods longer than 72 hours (to test this hypothesis) is under consideration. When such testing is performed, the results will be considered in future models.*

We have also raised doubts, in our review of M6.EVP.001 and M6.EVP.005, about the validity of the resting loss concept. Those objections carry over to the multiple day tests of diurnal losses, but their implication is not addressed here.

> *We continue to disagree with this reviewer on the issue of resting loss emissions.*

To the extent that report conclusions provide estimates of the multiple day effects, it is believed that the estimates can be refined with relatively little effort. Approaches applicable to that refinement are spelled out and to some extent demonstrated in this review.

4. REFERENCES

Time and resources did not permit extensive review of references applicable to M6.EVP.003. Reviews of M6.EVP.001 and M6.EVP.005, however, are incorporated as part of the present review, to the extent that comments on those two documents deal with corresponding issues in M6.EVP.003. Following is a list of references affecting this review.

1) Landman, L. C., Evaluating Resting Loss and Diurnal Evaporative Emissions Using RTD Tests. Document Number M6.EVP.001. (Draft) November 20, 1998

2) McAdams, H.T., Review of Draft Report M6.EVP.001. February, 1999.

3) Landman, L. C., Modeling Diurnal and Resting Loss Emissions from Vehicles Certified to the Enhanced Evaporative Standards. Document Number M6.EVP.005. (Draft) October 1, 1998

4) McAdams, H. T., Review of Draft Report M6.EVP.005. February, 1990.

Appendix B-1

Appendix to Peer Review Report

DEMONSTRATION DATA

	X1	X2	X3	Y	Z
	0	0	0	13.4	2.5953
	0	0	0	17.6	2.8679
	0	0	1	10.5	2.3514
	0	0	1	7.1	1.9601
	0	1	0	20.6	3.0253
	0	1	0	31.3	3.4436
	0	1	1	8.0	2.0794
	0	1	1	8.8	2.1748
	1	0	0	30.2	3.4078
	1	0	0	29.2	3.3742
	1	0	1	18.3	2.9069
	1	0	1	24.7	3.2068
	1	1	0	32.3	3.4751
	1	1	0	31.1	3.4372
	1	1	1	27.6	3.3178
	1	1	1	20.1	3.0007
	0	1	0	22.4	3.1091
	1	1	1	25.3	3.2308
	1	0	1	24.8	3.2108
	1	1	1	27.1	3.2995
Mean	0.55	0.55	0.55	21.52	2.9737 Exp(2.9737) = 19.5642
Std	0.5104	0.5104	0.5104	8.3050	0.4851 Exp(0.4851) = 1.6243

REGRESSION COEFFICIENTS FOR DEMONSTRATION DATA

	Log	Antilog
Constant	2.7624	17.6572
X1	0.7430	12.7385
X2	0.1803	3.6462
X3	-0.5391	-9.3615
R-square	0.7981	0.8203

Appendix B-1 (CONT.)

CALCULATED RESPONSE AND RESIDUALS

	Y	Calculated Responses		Residuals	
		Y-space	Z-Space*	Y-space	Z-space
	13.4000	17.6572	15.8381	-4.2572	-2.4381
	17.6000	17.6572	15.8381	-0.0572	1.7619
	10.5000	8.2957	9.2376	2.2043	1.2624
	7.1000	8.2957	9.2376	-1.1957	-2.1376
	20.6000	21.3034	18.9676	-0.7034	1.6324
	31.3000	21.3034	18.9676	9.9966	12.3324
	8.0000	11.9420	11.0628	-3.9420	-3.0628
	8.8000	11.9420	11.0628	-3.1420	-2.2628
	30.2000	30.3957	33.2960	-0.1957	-3.0960
	29.2000	30.3957	33.2960	-1.1957	-4.0960
	18.3000	21.0342	19.4199	-2.7342	-1.1199
	24.7000	21.0342	19.4199	3.6658	5.2801
	32.3000	34.0420	39.8749	-1.7420	-7.5749
	31.1000	34.0420	39.8749	-2.9420	-8.7749
	27.6000	24.6805	23.2571	2.9195	4.3429
	20.1000	24.6805	23.2571	-4.5805	-3.1571
	22.4000	21.3034	18.9676	1.0966	3.4324
	25.3000	24.6805	23.2571	0.6195	2.0429
	24.8000	21.0342	19.4199	3.7658	5.3801
	27.1000	24.6805	23.2571	2.4195	3.8429
Sum				0.0000	3.5901
Std.				3.5202	4.9356

Appendix C

Response to Written Comments from Stakeholders

The following comments were submitted in response to EPA’s posting a draft of this report on the MOBILE6 website. The full text of each of these comments is posted on the MOBILE6 website.

In responding to (and incorporating) comments from the peer reviewer (as well as from stakeholders), this final version of the report has changed substantially from the earlier draft version that was reviewed. Some of those changes have resulted in many of the comments no longer being applicable.

Comment Number: 74

Name / Affiliation: James M. Lyons / Sierra Research

Date: May 28, 1999

Comment:

"Before addressing the problems with the EPA proposal, one point that needs to be made is that it is unclear whether the data that were used in the EPA analysis had been adjusted to correct for the elimination of resting losses. Since resting losses are treated separately from diurnal losses by both MOBILE5a and the proposed MOBILE6, EPA needs to assure that resting losses are properly dealt with."

EPA’s Response:

No. These estimates are for the second and third days of the RTD tests. The diurnal emissions are obtained by subtracting the estimated resting loss emissions (see report M6.EVP.001) from these predicted RTD test results.

Comment:

"Returning to the EPA approach, the problems begin with the form EPA has postulated for Equation 2, which does not appear to be reasonable. For example, assuming that day i is day 1, the term D = 0 and day 1 emissions as predicted by Equation 2 for all vehicle types, regardless of purge/pressure test status, is a function of only RVP and temperature. In addition, day 1 emissions based on Equation 2 are also not a function of vehicle age (e.g., model year).

Clearly, this is not correct, nor is it the manner in which MOBILE5a or MOBILE6 treats day 1 diurnal emissions."

EPA's Response:

This report has been revised to incorporate the comments received. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment:

"The second problem deals with EPA's differentiation of Equation 2 with respect to D. Equation 2 is a discontinuous function of D, since values of D are restricted to integers (e.g., 1, 2, 3). As a result, if one plots emissions versus D using Equation 2 for three days, one would see three discrete data points and not a continuous curve. Since the derivative of discontinuous functions cannot be taken, there is no mathematical basis for Equation 4. Since EPA uses this equation as the underlying basis for the multiple-day diurnal correction factors derived from the agency's statistical analysis, there is no real basis supporting the current EPA approach."

EPA's Response:

This report has been revised to incorporate the comments received. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment:

"In the statistical analysis described in the draft report, EPA indicates that the analysis was performed using the "ESTIMATE" function in SAS. While we are not directly familiar with this function, the basic EPA approach was to attempt to estimate the regression coefficients (i.e., the b_1 terms) in Equation 2 using linear regression techniques applied to the entire multiple-day diurnal emissions database (e.g., all vehicles regardless of the fuel metering system or purge/pressure status). These constants would then be inserted into Equation 4, which EPA incorrectly derived from Equation 2, to yield estimates of the percentage change in diurnal emissions on day 2 relative to day 1 and on day 3 relative to day 2. As a result, the values of regression coefficients are different for the day 2 to day 1 and day 3 to day 2 comparisons.

"Even if one ignores the problems underlying EPA's basic approach, additional problems can be seen in the results of the statistical analysis documented in the draft report. The first issue is that there are relatively few data for carbureted vehicles. Therefore, one would expect that it will be difficult to develop statistically sound regression coefficients for these vehicles. Turning to the analysis itself, an example of additional problems can be seen in the results of EPA's first attempt to fit the multiple-day diurnal database to Equation 2, which are shown in Tables 2(a) and 2(b) of the EPA draft report (attached). Several facts are apparent from a quick review of these tables. First, the estimates of the intercept term b_0 are not reported. These are important because, without them, it is impossible to compare the emission values predicted by Equations 2 and 4 to the actual emission values. Obviously, such a comparison needs to be made in order to assess the validity of the derived equations."

EPA's Response:

This report has been revised to incorporate the comments received. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment:

"Next, as expected, the RVP and temperature terms have the strongest correlation with the magnitude of diurnal emissions (in terms of grams per day) on all days of a multiple-day diurnal event. Therefore, it is these variables that account for most of the variation in the daily diurnal emission rates explained by the EPA equations. However, since the purpose of the EPA analysis is to determine the increase in emissions relative to day 1 on subsequent days of a diurnal episode, and EPA concludes that RVP and temperature should not be considered in evaluating this increase (page 7), it is not clear why EPA chose to include these variables in the statistical analysis. Instead, it seems that EPA should have fit the percentage differences in emissions from one day to the next using Equation 4. Based on the large variations in the percentage changes in emissions from day to day for different vehicles in the database, we expect that if this had been done, very poor regression results would have been obtained. This in turn would highlight the basic difficulties associated with using the EPA approach to develop multiple-day diurnal correction factors."

EPA's Response:

This report has been revised to incorporate the comments received. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment:

"Moving on, the remaining coefficients associated with terms that are statistically significant at the 95% confidence level (as shown in the tables by Pr > T values of 0.05 or less) are all negative, as shown in the attached Tables 2(a) and (b) of the draft EPA report. If one recalls that the basic HC emission estimate derived from Equation 2 applies to fuel-injected P/P vehicles, these results indicate, for example, that diurnal emissions on the second day of a multiple-day event from fuel-injected F/P, F/F, or P/F vehicles are lower than those for P/P vehicles. Clearly, this is not what one would intuitively expect, nor is it what the data themselves indicate, as shown in the table on page 6 of the draft EPA report."

EPA's Response:

Section 4.2.4 has been added to this report to address this problem.

Comment:

"The reasonableness of the multiple-day correction factors EPA proposed can also be evaluated by simply comparing them to the data from which they were derived. This has been done for fuel-injected P/P vehicles by plotting the ratio of day 2 and day 3 emissions to day 1 emissions. These plots are shown in the attached Figures 1 and 2, respectively. Also shown are the lines representing the EPA correction factors (1.365 for day 2/day1 and 1.791 for day 3/day 1) and the lines representing the average values for the data sets. As can be seen from the figures, there is a large degree of variability in these ratios. In many cases, the values are less than one, indicating lower rather than higher diurnal emissions on subsequent days of a multiple-day event. This high degree of variability, as discussed below, is not surprising since EPA has assumed that RVP and temperature are not important."

EPA's Response:

This report has been revised to incorporate the comments received. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment:

"Also, it is not clear from the EPA database that all multiple-day diurnal testing was performed at the same fuel tank fill level. Since the amount of vapor generated during a diurnal depends on the magnitude of vapor space in the fuel tank, differences in fill level under different testing programs could be making some contribution to the observed variability."

EPA's Response:

The fill levels were the same for all of the multi-day tests.

Comment:

"Other observations that can be made regarding the data in Figures 1 and 2 include the fact that average values for the data sets are much greater than one and are substantially higher (1.3 times greater for day 2 and 2 times greater for day 3) than correction factors derived by EPA. Based on the above, EPA's statistical analysis notwithstanding, it is not at all clear to us that the correction factors EPA derived are in any way superior to the average values obtained from the data sets. What is clear, given the scatter in the data, is that both the averages and the EPA correction factors are not very robust estimates of changes in emissions that occur on the second and subsequent days of a multiple-day diurnal. Our overall conclusion is that there are fundamental problems that suggest that the current EPA approach needs to be abandoned in favor of an approach similar to one of the alternatives described below.

"We believe that the current EPA approach needs to be abandoned and that a complete reanalysis of the EPA multiple-day diurnal database along the lines described above is clearly warranted. In any case, the treatment of multiple-day emissions should at least be consistent with the physical effects that are known to be controlling the process. For vehicles with high day 1 emissions and low emission control system efficiencies, it may turn out to be acceptable to simply use day 1 emission rate estimates to represent emissions on subsequent days. However, for vehicles with low to moderate day 1 emissions and moderate to high emission control system efficiencies, substantial changes in emission rates that are related to a number of factors can occur and these changes should be taken into account in MOBILE6."

EPA's Response:

As this reviewer suggested, the approach used in the previous draft version of this report was "abandoned," and a "complete reanalysis" was performed. This revised approach has eliminated (avoided) this problem in this final version of the report.

Comment Number: 75

Name / Affiliation: David Lax / API

Date: June 8, 1999

Comment:

This submission is simply a cover letter for the previous item (Comment number 74 from Sierra)

EPA's Response:

See comments on previous item.

Comment Number: 78

Name / Affiliation: Tom Darlington / Air Improvement Resource, Inc.

Date: June 23, 1999

Comment:

The test program used to obtain the data, although not described in the report, is a highly suspect source of good data due to numerous problems with the way the program was conducted.

EPA appears to have ignored the Auto/Oil and CRC multiple-day test data, which was tested correctly and could be used for this purpose.

EPA's Response:

The testing was performed correctly. In fact, the same contractor was used by both EPA and CRC for the RTD testing. As to the "ignoring" CRC test data, we added the last paragraph in Section 2.0 (page 3) to address this point.

Comment:

There are errors in the data sample Table 1.

EPA's Response:

The errors in Table 1 have been corrected.

Comment:

Industry agrees that passing vehicles should not be higher than failing vehicles, but this is a function of the relative emissions on the first day.

EPA's Response:

This assumption is applied (in MOBILE6) to each day of diurnal emissions.

Comment:

The factors are also not appropriate for vehicles certified to enhanced evaporative emission standards. EPA may not have intended to use them for vehicles subject to the enhanced evaporative standards, but the report is not clear on this point.

EPA's Response:

Section 4.2.3 has been added to clarify this point.

Comment:

The report does not indicate how the analysis will fit in with the rest of the diurnal emissions analysis, i.e., the partial day diurnals, the full day diurnals, the activity data, etc.

EPA's Response:

The last paragraph of Section 5.0 has been added to address this point.